FORUM OF REGULATORS

STUDY ON
IMPACT OF ELECTRIC VEHICLES ON THE GRID

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Contents

List of Tables

List of Figures

Abbreviations

AIS	Automotive Industry Standards
ARAI	Automotive Research Association of India
BEV	Battery Electric Vehicle
BMS	Battery management system
CAISO	California Independent System Operator
CCS	Combined Charging System
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CO_2	Carbon Dioxide
CPP	Critical Power Pricing
CPUC	California Public Utilities Commission
CTU	Central Transmission Utility
DC	Direct Current
Discom	Electricity Distribution Company
DoER	Department of Energy Resources
DR	Demand Response
DSO	Distribution System Operators
EU	European Union
EVPP	Edison EV Virtual Power Plant
EVs	Electric Vehicles
EVSE	EV Supply Equipment
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India
FOR	Forum of Regulators
HEV	Hybrid Electric Vehicle
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEGC	Indian Electricity Grid Code
IOT	Internet-of-things
ISGS	Inter-state Generating Stations
ISO	International Organization for Standardization
ISP	internet service provider
ISTS	Inter-state Transmission Stations
kV	Kilo-Volt
KVA	Kilo-Volt Ampere
kW	Kilo-Watt
kWh	kilo-watt hour
LAAFB	Los Angeles Air Force Base
METI	Ministry of Economy, Trade and Industry, Japan
MOST	Ministry of Science and Technology, China
MUs	Million Units
NDRC	National Development and Reform Commission
NEMMP	National electric Mobility Mission Plan
NGR	Non-Generating Resource
NLDC	National Load Dispatch Centre
NVE	Norwegian Water Resources and Energy Directorate
PEVs	Plug-in electric vehicles
PG&E	Pacific Gas and Electric
PHEV	Plug-in Hybrid Electric Vehicle

PIVCO	Personal Independent Vehicle Company
PSB	Vermont Public Service Board
RE	Renewable Energy
RFP	Request for Proposal
RLDC	Regional Load Dispatch Centre
RTP	Real-time pricing
SCE	South California Edison
SDG&E	San Diego Gas and Electric
SERC	State Electricity Regulatory Commission
SLDC	State Load Dispatch Centre
SOC	State of Charge
STU	State Transmission Utility
ToD	Time of Day
ToU	Time of Use
USD	US Dollar
USDOE	U.S. Department of Energy
VAT	Value Added Tax
VEIC	Vermont Energy Investment Corporation
VGI	Vehicle Grid Integration
VLITE	Vermont Low Income Trust for Electricity
WDAT	Wholesale Distribution Access Tariff
ZEM2ALL	Zero Emission Mobility to All
ZEV	Zero-Emission Vehicle

Executive Summary

ES.1. Background and Objectives of the study

The transport sector is the largest user of oil and second largest source of CO_2 emissions world-wide. Indian transportation sector accounts for one-third of the total crude oil consumed in the country, where 80% is being consumed by road transportation alone. It also accounts for around 11% of total CO_2 emissions from fuel combustion. The National Electric Mobility Mission Plan 2020, notified by the Department of Heavy Industry, Ministry of Heavy Industries and Public Enterprises, Government of India seeks to enhance national energy security, mitigate adverse environmental impacts from road transport vehicles and boost domestic manufacturing capabilities for Electric Vehicles (EVs). The Indian Government under the FAME scheme is incentivizing the use of EVs and development of the required ecosystem. As per a recent report, policy think-tank Niti Aayog also supports incentivizing electric vehicle (EV) while discouraging privately-owned petrol and diesel-fueled vehicles. As more EVs populate the roads, utilities are likely to become increasingly concerned with managing and making use of these 'mobile assets', to avoid any adverse impact on the Indian electricity grid. Facilitative framework created by regulators, related to enabling business models and attractive tariffs can offer interesting system benefits.

Forum of Regulators (FOR), taking a pro-active stance, commissioned this study to assess the techno-economic impact of large scale penetration of electric vehicles, on the grid; and to evolve appropriate regulatory framework to facilitate roll out of the electric vehicles in the country. The study was carried out to answer the following questions – (1) What are the international best practices for EV integration and promotion? (2) What has been the role of regulators and distribution distribution licensees in the uptake of EVs?, (3) What would be the impact of EV load on the local distribution system?, (4) What business models can be developed for public charging infrastructure development in the context of the Electricity Act, 2003?, and (5) What would be the tariff impact of a distribution utility's investment in public charging infrastructure? These questions are explored in the report and summarized here.

ES.2. Lessons Learnt from International Experience

Electricity regulators have played a pro-active role in promotion of EVs and have directed or in some cases mandated electricity distribution companies to invest in EV charging infrastructure. Key interventions made by the regulators and the electricity distribution companies are listed below.

1. Regulators in California and Vermont have approved the capital expenditure towards EV Supply Equipment (EVSE)[1] installations as a part of rate base.
2. Electricity distribution companies have offered attractive time-of-day tariffs to promote off-peak charging.
3. They have also played a key role in the development of public charging infrastructure.

[1] EVSE referes to the the physical charger, cable, connector and management software necessary to safely deliver electricity to charge the batteries of an electric vehicle.

4. Besides, electricity distribution companies in US, Japan and China are experimenting with utilization of EVs as grid assets, either by using them as a demand response resource or for providing ancillary services through Vehicle-to-Grid technologies.

Review of international policies also bring forward importance of fiscal interventions by the Governments, which are listed below.

1. Governments across the world offer substantial direct and indirect incentives to EVs. Direct incentives include purchase subsidy for EVs and subsidy for installation of chargers while indirect benefits range from tax breaks to access to reserved lanes and parking spots,
2. France offers an CO_2 emission based "feebate" system, which subsidizes electric vehicle purchase while penalizing higher-emission vehicles.

Table 1 below summarizes policy, fiscal and regulatory best practices and presence of market-players from key global market leaders.

Table 1: Comparative analysis of best practices from case studies

			US		Norway	France	China	Japan
			Vermont	California				
Policy Support	Targets for EVs		✓	✓	✓	✓	✓	✓
	Government commitments / legislation for EVs		✓	✓	✓✓	✓	✓✓	✓
Fiscal incentives provided	Direct subsidies on EV purchase	Upfront	✓	✓	✓✓	✓✓	✓✓	✓
		Offered to leased vehicles		✓✓	✓✓	✓✓	✓✓	✓✓
		Available for Company vehicles		✓✓	✓✓	✓✓	✓✓	✓✓
		Available for a definite period	✓	✓✓	✓✓	✓	✓	✓✓
	Indirect incentives (Road tax waiver, VAT waiver, access to reserved lanes, free parking)		✓	✓✓	✓✓	✓	✓✓	✓✓
Regulatory directives and role of utilities	Directives from regulator on EVs			✓		✓		
	Regulatory orders			✓				
	Approval of Budget/electrical tariff		✓	✓	✓	✓	✓	✓
	Utility initiatives and programs		✓	✓	✓	✓	✓	✓
	Time of use tariff		✓	✓✓	✓	✓	✓✓	✓
Domestic EV Auto Industry	Local EV manufacturer			✓✓	✓	✓✓	✓✓	✓✓
	Battery manufacturing			✓	✓	✓	✓✓	✓✓
EVSE business	Private players		✓	✓✓	✓✓	✓✓	✓	✓✓
	Utility/Government		✓	✓✓	✓✓	✓	✓✓	✓

✓ Support available ✓✓ High support available

ES.3. Technical impact of EVs on the Grid

The electrical vehicle load is non-linear and can cause harmonic distortion, DC offset, phase imbalance, and voltage deviations in the distribution network. However, with approximately 5000 MW of EV related additional load expected to come on to the system, at the national grid level, the impact is negligible. In this study, Matlab/Simulink platform was used to analyze the effect of charging of batteries on different feeder systems. Based on EV charging profiles considered in the simulations; a baseline 50% loaded commercial feeder can safely absorb up to 20% of additional EV load from fast charging, similarly the residential feeder, can be safely handle a ratio of 60%:40% from Residential load and EV load (fast charging) respectively. However, the peak co-incident charging scenario showed that a loading of around 20% from fast chargers should be the threshold. This implies that should such high loading conditions occur, the distribution licensees should build resilience by network expansion. The impact from slow charging on both the feeders was negligible.

ES.4. Legal aspects and possible business models

In the context of Electricity Act 2003 (The Act) and its provisions, the following observations are made:

1. As per The Act, the provision of public EV charging service to the users amounts to distribution/supply of electricity.
2. Specific amendments to the Act can be made, allowing EV charging businesses to resell the electricity without specific licensing arrangements,
3. In the current legal provisions, following three business models are feasible, which are detailed in Figure 1: Business models:
   a. Distribution Licensee owned EV charging infrastructure,
   b. Distribution Licensee Franchised EV charging infrastructure, and
   c. Privately-owned battery swapping stations

Distribution Licensee-owned EV charging infrastructure

- Supply of electricity to vehicle owners would be part of the activities of the Distribution Licensee

❿ The retail supply tariff for supplying to the electric vehicle owners will be determined by the SERC

Distribution Licensee franchised EV charging infrastructure

- Utility can authorize a third party (Franchisee) to install and/or operate charging stations on its behalf in its area of supply. The franchisee can also be a public private partnership (PPP)

❿ Charging stations can receive electricity at a single point as bulk supply. The single point supply tariff as well as the tariff cap for retail sale will be determined by the SERC

❿ Franchisee can be allowed to purchase power through open access without applying Cross Subsidy Surcharge

Privately-owned battery swapping stations

- Utility, its distribution franchisee or any other third party can aggregate the demand for batteries and set up battery swapping stations

❿ Battery swapping will not amount to electricty resale and hence third parties can set up the stations with intimation to the Distribution Licensee to avail special category tariff.

❿ The Charging Station can receive electricity in bulk at single point from a distribution licensee or through open access to charge the batteries, as per provisions of the Act.

❿ The bulk supply tariff/single point supply tariff will be determined by the SERC

Figure 1: Business models for EV charging infrastructure

ES.5. Tariff impact of investments in EV charging infrastructure

As EV penetration in India requires substantial boost through development of EV charging infrastructure, the tariff impact of distribution licensee's investment is estimated through the following scenarios.

1. Two primary scenarios were studied for their tariff impacts –
   (i) NEMMP targets and corresponding EV charging infrastructure requirements and
   (ii) An aggressive target termed the NEMMP+ aligned with the Ministry of Power's draft note highlighting expected vehicle stock,
2. Both NEMMP and NEMMP+ scenarios use Low Growth and High Growth options
3. In both the scenarios, the study used specific assumptions related to the cost of EV charging infrastructure as no specific market data is available,
4. Tariff impact assessment was carried out in two formats –
   (i) Entire investment socialized to all the consumers of the licensee and
   (ii) Investments charged only to the EV category
5. Insignificant tariff impact is noticed in both the scenarios as seen in Table 2

Table 2: Levelized tariff impact for investment in public EV charging infrastructure

Scenario	Business models	Growth options	Tariff Impact (Rs./kWh)
NEMMP	Scenario 1A: Investments socialized to all the consumers	Low Growth	0.0007
		High Growth	0.0010
	Scenario 1B: Investments charged only to EV category sales	Low Growth	0.2810
		High Growth	0.2097
NEMMP+	Scenario 2A: Investments socialized to all the consumers	Low Growth	0.0013
		High Growth	0.0040
	Scenario 2B: Investments charged only to EV category sales	Low Growth	0.1912
		High Growth	0.1790

By promoting night time charging, the fixed charges or capex investments paid by the utility to generators can also be capitalized by offering aggressive time-of-day (ToD) tariffs. The report discusses the possible special category tariffs and ToD tariff, taking a distribution licensee (MSEDCL) as an example.

ES.6. Recommendations

While the Regulatory aspects will have to be dealt with by the Appropriate Commission, it would be advisable for the sake of uniformity and harmony of Regulations, to have suitable provisions in the Tariff Policy or in the Rules, on the following interventions:

1. Regulators to allow pass through of investments made in EV charging infrastructure by the Dsitribution licensees in tariffs
2. Create simplified framework for franchise agreements between the distribution licensees and private sector/interested Public Sector Undertakings/associations for setting up public charging infrastructure.

3. Allow distribution licensees to appoint multiple and non-exclusive franchisees within its area of supply for setting up public charging infrastructure. Annexure V to this report includes suggested "**Draft Franchisee Agreement for EV Charging Infrastructure Operators**" to be signed with the incumbent distribution licensee.
4. Create new tariff category for EVs by allowing recovery of incremental cost of infrastructure through wheeling charges over and above the average cost of service. Annexure VII to this report includes suggestions on "**Broad Principles of Special Category Tariff**".
5. Allow special ToD structure for EV charging infrastructure accounting for use of backed-down assets in the night time
6. Allow Open Access to EV charging infrastructure aggregators without cross subsidy surcharge. Also allow banking of RE generation to promote reduced tariffs.
7. In order to encourage the use of renewable energy to meet the demand created by EVs, either directly or by way of substitution; appropriate incentive mechanism should be designed for such consumption.

Chapter 1: Introduction

The transport sector is the largest user of oil and second largest source of CO_2 emissions world-wide. Indian transportation sector accounts for one-third of the total crude oil consumed in the country with 80% of this being consumed by road transportation alone. It also accounts for around 11% of total CO_2 emissions from fuel combustion. The National Electric Mobility Mission Plan 2020, notified by the Department of Heavy Industry, Ministry of Heavy Industries and Public Enterprises, Government of India seeks to enhance national energy security, mitigate adverse environmental impacts from road transport vehicles and boost domestic manufacturing capabilities for Electric Vehicles (EVs). It is envisaged that EVs are expected to play a significant role in India's transition to a low-carbon eco-system.

Distribution Licensees (DLs or Discoms) and Electricity Regulatory Commissions are expected to be amongst the most critical stakeholders in the EV landscape. As more EVs populate roads, distribution licensees are likely to become increasingly concerned with managing and making use of these 'mobile assets'. Distribution licensees thus need to be informed about the benefits that they can derive from EVs and about the innovative mechanisms that they can devise to avoid adding stress to the grid from charging of EVs. Distribution licensees should not perceive EVs as an additional burden on the grid, which could hinder the large-scale adoption of EVs. Similarly, regulators need to create an enabling framework and attractive rate structures for charging, such that peak hour charging is avoided and is shifted to off-peak hours. Hence it is very important to equip both regulatory and utility personnel with the technical and managerial aspects of the EV landscape.

Recognizing this need, Forum of Regulators (FOR) mandated MP Ensystems to study and assess the impact of electric vehicles on grid requirements and capacity and develop the necessary framework to enable implementation. Specific questions explored under this study are listed here:

(1) What are the international best practices for EV integration and promotion?

(2) What has been the role of regulators and distribution distribution licensees in the uptake of EVs?

(3) What would be the impact of EV load on the local distribution system?

(4) What business models can be developed for public charging infrastructure development in the context of the Electricity Act, 2003?

(5) What would be the tariff impact of a distribution utility's investment in public charging infrastructure?

In this report, literature reviews and best practices followed by international leaders have been assessed, a basic techno-economic assessment of the impact of EVs on the grid has been carried out and legal provisions of Electricty Act, 2003 were studied to identify possible business models for creation of public charging infrastructure. This report has been organized in the following six chapters:

1. In Chapter 2, the policies and best practices of leading countries with the highest share of EVs in the vehicle population has been analyzed along with current and completed EV-grid integration pilots and the business models for public charging infrastructure
2. In Chapter 3 , the impact of EVs on local distribution transformers is assessed on the Matlab/Simulink platform

3. In Chapter 4, possible business models for investment in Public EV Charging Infrastructure in the context of the Electricity Act, 2003, have been assessed
4. In Chapter 5, a detailed economic assessment of EVs and their value to the distribution licensees including the tariff impact for investment in public charging infrastructure has been carried out
5. In Chapter 6, the Grid Code and draft Automotive Industry Standards (AIS) for EV Charging has been reviewed in addition to listing of current efforts at the Bureau of Indian Standards (BIS) and Central Electricity Authority (CEA)
6. In Chapter 7, provides the recommendations and way forward.
7. The report has two specific Annexures that can be used as guidelines. These are Annexure V**: Draft Franchisee Agreement for EV Charging Infrastructure Operators** and Annexure VII**: Broad Principles of Special Category Tariff.**

Chapter 2: International best practices and case studies

Recognizing the importance of EVs in the future of sustainable mobility, several countries have launched and announced their ambitious electric mobility missions and are supporting EV charging infrastructure development. This chapter is divided into three sections:

1. Country level commitments and promotional policies for incentivizing use of EVs (2.1)
2. Completed and ongoing EV gird integration pilots (2.2)
3. Business models followed world-wide for development of public charging infrastructure (2.3)

2.1 Country Strategies and Incentives for Promoting EVs

The Governments and different energy market structures have led to a wide variety of programs that support and adapt to EVs, and a number of trends and best practices have begun to emerge across jurisdictions. This study has focused on assessing the national strategies and best practices followed by the following countries:

i. United States – States of Vermont and California;
ii. Norway
iii. France
iv. China
v. Japan.

Further, the EV strategies and best practices in these countries have been assessed on the following parameters:

i. Drivers
ii. Policy support
iii. Incentives provided
iv. Regulatory directives and role of utilities
v. Public investment/expenditure
vi. Pricing models for EV charging
vii. Impact on Grid
viii. Policy Impact on share of EVs/consumer perception.

2.1.1. United States: EV Everywhere Grand Challenge

EV Everywhere is an umbrella effort by the U.S. Department of Energy (DOE) to increase the adoption and use of plug-in electric vehicles (PEVs). EV Everywhere was announced in March 2012, with the aim of enabling plug-in electric vehicles to be as affordable and convenient as gasoline-powered vehicles by 2022 (Department of Energy, 2017). Under this challenge various states and cities have initiated and enhanced their push for electric vehicles.

2.1.1.1. Drive Electric Vermont

The Drive Electric Vermont (DEV) Program was formulated in 2012 and is a public-private partnership between three Vermont State agencies and the nonprofit Vermont Energy Investment Corporation (VEIC), aimed to increase the use of electrified transportation in the State (VEIC, 2017).

<table>
<tr><th>Parameter</th><th colspan="2">Details</th></tr>
<tr><td>Drivers</td><td colspan="2">i. Incentives and Grants complemented by State Government, Government Agencies', Foundations and utilities
ii. Early and broad stakeholder involvement
iii. Extensive involvement of the utility in setting-up of infrastructure
iv. Strategic outreach and education activities to raise public awareness
v. Receptive PEV culture in Vermont</td></tr>
<tr><td>Policy Support</td><td colspan="2">i. Part of the EV Everywhere Grand Challenge of US Department of Energy[2]
ii. Member state for zero-emission vehicle (ZEV) program, which targets to have at least 3.3 million ZEVs operating on roadways by 2025 in member states</td></tr>
<tr><td>Incentives provided</td><td colspan="2">i. Purchase incentives[3]
ii. Federal Tax Credits for the Purchase of Electric Vehicles up to USD 7,500 depending on the size of the battery
iii. Federal Tax Credits for Electric Vehicle Charging Equipment 30% tax credit up to USD 1,000 for residential 30% tax credit up to USD 30,000 for commercial property owners
iv. Bill credits from utilities for purchase of plug-in electric vehicles</td></tr>
<tr><td rowspan="5">Regulatory directives and Initiatives by utilities</td><td colspan="2">i. Vermont Comprehensive Energy Plan includes provisions supporting the use of PEVs
ii. Tier III category of Vermont's Renewable Energy Standard requires utilities to offset customer fossil fuel usage, most commonly by incentivizing use of PEVs[4]
iii. Vermont Public Service Board (PSB) has reviewed and approved fees/tariffs charged by the distribution Utilities at their public charging locations [5]
iv. Utilities have made significant amount of investment in EV Supply Equipment (EVSE) by buying and coordinating placement of EVSE.[6]</td></tr>
<tr><td>Utility</td><td>Specific Actions</td></tr>
<tr><td>Green Mountain Power</td><td>• Owns and hosts charging stations and has a broader partnership with NRG Energy (EV infrastructure provider).
• Installs EVSE on its own cost, while the host pays the cost to run electrical service by paying a monthly fee
• Offers incentives for stations connected with solar rooftop</td></tr>
<tr><td>Burlington Electric Department</td><td>• Covers the cost of the equipment and installation out of their capital budget</td></tr>
<tr><td>Washington Electric Co-Op</td><td>• Provides the cost for installation (covered by a USD 1,47,000 grant from VLITE[7]), Offers free lease to and free service contract to host for 5 years</td></tr>
</table>

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[2] DOE during 2013-14 invested USD 225 million in research and development (R&D) efforts which led to substantial reduction in the production cost of batteries

[3]

Utility	Incentive
Burlington Electric Department	USD 1,200 rebate on the purchase or lease of a new All Electric Vehicle or USD 600 on a Plug-in Hybrid Electric Vehicle priced below USD 50,000
Green Mountain Power in partnership with Nissan	USD 10,000 purchase rebate on new 2017 Nissan LEAF electric vehicles
Vermont Electric Coop	USD 250 bill credit for the purchase of a new or used plug-in electric vehicle, USD 50 bill credit for leased vehicles for each year of the lease

[4] *Ibid at 2, (Public Service Board, 2017)*

[5] *Communication with Mr. David Roberts, VEIC*

[6] *(Wagner, Roberts, Francfort, & White, 2016)*

Parameter	Details		
	Stowe Electric	• *Offers a cost share of 75% of the equipment cost (funding from VLITE), with the hosts providing the balance 25%*	
Public Investment/ Expenditure	*Total public expenditure incurred on the program except the purchase incentives USD 1,15,000 as one-time cost and USD 95,000 as recurring cost*[8]		
Pricing structure for EV charging	***Pricing models***	***Utility rate structure for paid public charging stations***	
	i. Most locations offer free charging *ii. Monthly memberships* *iii. Hourly payment (often with higher fee for the first hour followed by a lower hourly fee for the remaining hours)* *iv. Flat "access fee" in addition to the hourly rate* *v. Energy-based, where the user is charged per kWh drawn from the EVSE*	*Utility*	*Rate*
		Green Mountain Power	*monthly fee (typically USD 69 for dual port).*
		Burlington Electric Department	*"kick-off fee" of USD 1 per hour after 4 hours*
		Washington Electric Co-Op	*No separate EV charging tariff*
		Stowe Electric	*USD 1.93 as hook-up fee, USD 0.48 per hour for the first 4 hours, and 0.96 cents per hour thereafter*
Impact on Grid	*The current population of the PEVs is 1% of the vehicle population and hence grid impact is minimal*[9]*.* *Department of Energy Resources (DOER), Massachusetts announced its Vehicle-to-Grid Electric School Bus pilot program, targeting reduction of petroleum use by approximately 22,680 gallons of gasoline equivalent.*		
EV Population	*The number of PEVs grew from 88 in July 2012 to 1,113 in January 2016. The number of PEV charging stations grew from 17 in January 2013 to 111 in January 2016*[10]*.*		

Table 3: Overview of the Drive Electric Vermont scheme

2.1.1.2. California EV Program

California has historically had an aggressive regulatory strategy for automobiles to reduce air pollution in its auto dependent cities. With its Zero Emission Vehicles (ZEVs) regulations and high technology industry, it is home to advanced vehicle manufacturing facilities.

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[7] *Vermont Low Income Trust for Electricity (VLITE), a public benefit, non-profit corporation*
[8] *Ibid at 4*
[9] *Communication with Mr. David Roberts, VEIC*
[10] *(Wagner, Roberts, Francfort, & White, 2016).*

Parameter	Details
Drivers	*Activism of the California Air Resources Board and the California Energy Commission in regulating emission standards for vehicles*
Policy Support	*i. Adoption of Zero-Emission Vehicle program, (required major vehicle manufacturers to sell an increasing number of low-emission and zero-emission vehicles over time)* *ii. Adoption of a target of 1.5 million ZEVs by 2025 under its ZEV Action Plan.*
Incentives provided	*i. Federal and State purchase incentives up to USD 2,500 for EVs and up to USD 7,500 as tax credits depending on the battery capacity* *ii. Local government rebates for the purchase of EVs* *iii. Local government rebates for Electric Vehicle Charging Equipment* *iv. Free parking and charging at select locations* *v. Streamlined permission process for installation of residential chargers*
Regulatory directives and Initiatives by utilities	*i. CPUC approved investments of USD 45 million for SDG&E in 3,500 (Level 1[11] and Level 2) charging stations[12] and USD 22 million on a third-party owned to build about 1,500 (Level 1 and Level 2) charging stations for SCE. USD 160 million for PG&E's program for 7,500-Level 2 station and 100 DC fast chargers[13]* *ii. CPUC has developed a framework for Vehicle to Grid integration* *iii. Utilities are developing demonstration pilots for VGI and utilizing EVs as ancillary services*
Public Investment/ Expenditure	*Approximately USD 88 million in rebates have been issued*
Pricing structure for EV charging	*i. Monthly memberships* *ii. Flat access fee and time based or energy based fee* *iii. Time of use tariffs by utilities* *iv. Free usage at some public charging stations*
Impact on Grid	*Pre-empting the grid impact* *i. CPUC encouraging utilities to use EVs as a grid support asset (quick responding measure) and created a VGI framework to this end* *ii. Utilities have been offering aggressive ToU tariffs to shift charging to off peak hours and when the solar energy is available during daylight hours*
EV Population	*Total PEV registrations in the state were around 200,000 by December 2016. California accounts for half of the EV stock in US*

Table 4: Overview of California EV program

2.1.2. Norway EV Strategy

Norway has the world's highest share of PEVs per capita. In 2015 and 2016, electric vehicles accounted for a 23-29% share of new car sales (Hall & Lutsey, 2017). The Government supports electric cars by

[11] Level 1, Level 2 and Level 3 chargers are defined based on the voltage levels. In US Level 1 chargers operate on 120 V AC chargers and use the least amount of energy in a given time for charging batteries, Level 2 chargers operate between 208 - 240 V AC and are faster than Level 1 and used for home or workplace charging. Level 3 chargers operate on High Voltage DC current and can typically charge 80% of the batteries in 30 minutes or less.

[12] typical residential customer of SDG&E using 500 kilowatt-hours per month experience an increase of about 18 cents (0.02%) over the first year, at the end of three years, the increase relative to current rates would be about USD 2.75 on an annual basis.

[13] *(UtilityDive, 2016) (Lantry, 2016).*

employing "polluter pays principle" in the car tax system (high taxes for high emission cars and lower taxes for low and zero emission cars), which also impacts fiscal revenue.

Parameter	Details
Drivers	*i. Heavy reliance on cars for passenger transport, conditioned by relatively low population density and limited rail network* *ii. Stricter commitments for CO_2 level reduction to curb the transport sector's environmental impactundance of cheap hydro power* *iii. Extensive investment in public charging infrastructure* *iv. Innovations in vehicle technology – focus on lightweight automotive bodies instead of increasing the battery size and capacity (PIVCO)* *v. Ambitious targets legitimatized by the NGOs, and not-for-profits BEV interest groups* *vi. High price of gas to consumers. Unlike many oil producing countries, Norway does not subsidize gas prices and in fact, includes significant federal taxes.* *vii. Push by government, local bodies, industry association and not-for-profit bodies*
Policy Support	*i. Agreement on Climate Policy (Klimaforliket) with a commitment to greenhouse gas reduction target of 44 Gt of CO_2e per year by 2020, including a commitment to reduce emissions from the transportation sector[14].* *ii. CO_2 standard for new passenger cars to be 85 g/km by 2020[15].* *iii. Goal of having all new car sales as either zero emission (electric or hydrogen) or low (plug-in hybrids) emission by 2025.* *iv. A limit of 120–140 g CO_2 /km for new vehicle acquisitions in the government fleet (Norwegian government, 2007) and goal of having a CO_2-neutral fleet by 2020.*
Incentives provided	*i. No purchase/import taxes* *ii. Exemption from 25% VAT on purchase* *iii. Low annual road tax* *iv. No charges on toll roads or ferries* *v. Free municipal parking* *vi. Access to bus lanes* *vii. 50% reduced company car tax* *viii. Exemption from 25% VAT on leasing* *ix. Exemption from registration tax. Given the construct of the registration tax, PEVs are cheaper than conventional vehicles* *x. Special registration plate for BEVs using the prefix "EL." These special registration plates also increase the visibility of EVs [16]*
Regulatory directives and role of utilities	*The Norwegian Water Resources and Energy Directorate (NVE) determines general principles and approves the budget cap for Distribution System Operators (DSO). DSOs have been actively involved in installing public charging stations across their service areas. Fortum, an electricity supplier has the highest share of charging infrastructure. The network includes more than 1000 charging units (400 are quick chargers) across the nordic countries.*
Public Investment/ Expenditure	*By 2014, the program had cost the government USD 450 million (according to the Norwegian Ministry of Climate and Environment) including USD 7.4 million for charging station infrastructure[17], around USD 350 million of this is revenue foregone from VAT and registration tax revenues, and other indirect incentives.*

[14] *(Vergis, Turrentine, Fulton, & Fulton, 2014)*
[15] *(Tietge, Mock, Lutsey, & Campestrini, 2016)*
[16] *(Elbil, 2017)*
[17] *(Phillips, 2015)*

Parameter	Details
Pricing Models for EV Charging	*i. Energy based pricing models - Charges for per kWh used* *ii. Minute based pricing* *iii. Free Charging locations*
Impact on Grid	*Nord-Trondelag Elektrisitetsverk, national power grid operator, demonstrated that system can handle up to 20 percent penetration without system reliability breaches, if vehicles are less physically concentrated[18].*
EV Population	• *Norway had a stock of more than 135,000 EVs as on December 2016* • *More than 20% of all new vehicles sold in Norway are 100% electric*

Table 5: Overview of Norway EV strategy

2.1.3. France – EV Deployment

The adoption of plug-in electric vehicles in France is actively supported by the French government through various incentives. The government provides subsidies towards the purchase of all-electric vehicles and plug-in hybrids with low CO_2 emissions. The stock of light-duty plug-in electric vehicles registered in France passed the 100,000 units milestone in October 2016, making it the second largest plug-in market in Europe after Norway, and the world's fifth.

Parameter	Details
Drivers	*i. Ambitious CO2 emission reduction targets* *ii. To acheive higher energy independence and a shift towards a less oil intensive transport sector* *iii. To prioritize the development of EV technology with the aim to pioneer the technology and keep the value chain in the country* *iv. To achieve technological advancements and cost reductions across the EV value chain*
Policy Support	*i. The French Energy Transition for Green Growth Act of 2014* *ii. French government's 14-point plan, which aims to bring 2 million EVs on roads by 2020* *iii. Environmental legislation, Grenelle II[19]*
Incentives provided	*i. Feebates - penalizing vehicles penalty upto USD 8,960 with comparatively high CO_2 emissions values (≥130 g/km) and subsidizing vehicles with low emissions (≤110 g/km) with bonus up to USD 1,120.* *ii. "super bonus" for scrapping old diesel upto USD 4,150* *iii. Tax benefits based on CO_2 emission values[20]*
Regulatory directives and role of utilities	*Regulatory Activism* *i. Commission de régulation de l'énergie (French Regulatory Commission of Energy) issued direction for the utilities to facilitate development of EV charging businesses and recommended that energy code can specify that recharging is not considered as electricity supply[21]*

[18] *Ibid*
[19] *(IEA, 2017)*
[20] *(ICCT, 2016)*
[21] *(CRE, 2014)*

<table>
<tr><th>Parameter</th><th colspan="3">Details</th></tr>
<tr><td></td><td colspan="3">Utility initiatives
i. State-owned energy utility Électricité de France (EDF) plans to install 200 fast charging stations, also offers rebates on electricity during off-peak hours
ii. Partly publicly owned energy utility, Compagnie Nationale du Rhône plans to install an additional 52 fast charging points</td></tr>
<tr><td rowspan="5">Pricing structure for EV charging</td><td>Pricing models</td><td colspan="2">Pricing structure of private players[22]</td></tr>
<tr><td rowspan="4">Mix of public and private battery-charging stations.
i. Utilities offer a ToU price for EV charging.</td><td>Recharging method</td><td>Examples of prices for recharging (including parking and other services)</td></tr>
<tr><td>Slow recharge
(3 kW)</td><td>• Paris, Autolib': ~USD 9.53 during peak hours and ~USD 4.76 during off-peak hours, after an initial registration fee of ~USD 17.86
• Lyon, BlueLy: ~USD 21.43 during peak hours and ~USD 42.87 during off-peak hours + a set monthly fee of ~USD 17.86
• Saint Germain en Laye, Château car park: ~USD 2.86
• Mayenne, SDEGM: ~USD 9.53
• Toulouse, Law faculty: ~USD 14.29
• Toulouse, Compans Cafarelli: ~USD 14.29</td></tr>
<tr><td>Fast recharge
(22 kW)</td><td>Mayenne, SDEGM: ~USD 9.53</td></tr>
<tr><td>Ultrafast recharge
(44 kW)</td><td>Ultrafast recharging stations in public locations are generally free</td></tr>
<tr><td>Impact on Grid</td><td colspan="3">As per the French transmission network operator RTE, the peak from the fleet of two million electric vehicles (targeted by 2020), could add between 3 and 6 gigawatts (GW) of peak demand, which may affect the grid adversely (Reuters, 2013). However, investment in smart grid and off-peak charging can manage the grid impacts.</td></tr>
<tr><td>EV Population</td><td colspan="3">France had more than 1 lakh light duty electric vehicle by the end of December 2016</td></tr>
</table>

Table 6: Overview of France EV program

2.1.4. China EV Strategy

China's EV development is driven by a top-down approach. The central government is the initiator and main driver for EV development and supports every stage of the system from R&D, demonstration and promotion, commercialization to production and sales, scale-up, and charging infrastructure construction. So far, the subsidy policy of government is the main driver for EV enterprises to produce EVs and for consumers to buy EVs.

[22] *Ibid*

Parameter	Details
Drivers	*i. Electric Vehicles offer an opportunity to be the industry leader* *ii. EV strategy can help address the problem of high air pollution* *iii. Reduced dependence of oil-based fuel in China*
Policy Support	*i. Notice on Continuing to Carry out The Promotion and Utilization of New Energy Vehicles (caijian [2013] No. 551)* *ii. State Council's Plan of Energy-Saving and New Energy Vehicle Industry Development (2012-2020) (Guofa [2012] No.22)* *iii. MOST's Twelfth Ten-Year Special Plan for Science and Technology Development of Electric Vehicle* *iv. MOST's Energy-Saving and New Energy Vehicle Major Project under the Eleventh Five-Year Program* *v. MOST's Electric Vehicle Special Project under the Tenth Five-Year (2001-2005.)*
Incentives provided	*i. Tax credit for automakers* *ii. Reward to charging infrastructure construction* *iii. Subsidies for purchasing EV often matched by local governments* *iv. Tax reduction for purchasing EVs* *v. Mandated the use of electric vehicles by some government offices - In June 2014, the National Government Offices Administration announced a measure that electric cars make up at least 30 percent of government vehicle purchases by 2016.* *vi. Setting standards for electric vehicles*
Regulatory directives and role of utilities	*Chinese utilities have worked with cities to coordinate EVSE installations* *China Southern Power Grid Company is planning to install two free EV charging poles for each Shenzhen EV driver, one at the home and another near the driver's place of business.*
Pricing structure for EV charging	***Pricing models*** *ToU tariffs for EV charging* *i. Beijing electricity customers pay TOU (Time of Use) rates with seasonal adjustments*[23] *ii. Shenzhen EV drivers can sign up for reduced electricity rates, including off- peak prices of 0.3 yuan (USD 0.05) per kWh* [24]
Impact on Grid	*No discerning impact on the grid seen yet*
EV Population	*i. 3,600 public charging and swap stations and 49,000 chargers had been built by August 2016 and has a goal of 4.8 million chargers, 12,000 charging stations and bringing No. EV/No. chargers ratio to 1:1 by 2020.* *ii. Recently market has been opened to private players as well.* *iii. By December 2016, electric vehicle fleet of more than 951,000 vehicles including buses and trucks*[25]*.*

Table 7: Overview of China EV program

2.1.5. Development of EVs in Japan

The Japanese government has focused its PEV spending on vehicle incentives, subsidizing electric vehicle charging infrastructure, and infrastructure research and development. Faced with natural resource constraints, Japan is promoting sustainable and smart town concepts. In Fujisawa, Sustainable Smart

[23] *(Smith & Kim, 2016)*
[24] *(ICCT, 2013)*
[25] *(HybridCars.com, 2017)*

Town (Fujisawa SST) project, a former industrial plant has been converted into a smart community (a total of 3,000 persons). It is a joint project between the private and public sector, led by Panasonic Corporation. The town will include the service of sharing electric vehicles (EV) and electric-assisted bicycles as well as a rental car delivery service, and battery stations for renting rechargeable batteries (Panasonic Corporation, 2014) (FujisawaSST, 2017). Using an IOT platform, a mobility concierge/portal will make recommendations after considering the distance, hours of use, change in traffic conditions by time of day, from car sharing or rental car, including electric vehicles (EV). It also has EVs and V2home outlets installed. The project cost has been estimated to be 60 billion yen (USD 740 million) (Sim, 2016).

Parameter	Details
Drivers	*i. Lack of natural energy resources* *ii. Heavy dependence on imports for primary energy supply* *iii. Low availability of RE sources* *iv. Presences of world leaders in battery technology, automobile and components*
Policy Support	*Next Generation Automobile Industry Strategy, goal of having 15–20% EVs in 2020 and 20–30% EVs of in 2030 passenger vehicle market*
Incentives provided	*i. Purchase incentives for consumers* *ii. Reduction on acquisition tax (VAT)* *iii. Exemption from an annual tonnage tax during the first year and 50% reduction in the second year* *iv. Support to manufacturers* *v. Investment in R&D*
Regulatory directives and role of utilities	*The electric power companies of Japan have jointly decided to introduce about 10,000 electric vehicles (including plug-in hybrid vehicles) in total for commercial use by FY2020*
Public Investment/ Expenditure	*In 2011-12, allocation of USD 356 million to support charging infrastructure and purchase incentives in 2015, Ministry of Economy, Trade and Industry announced utilization of USD 360 million (supplementary budget from FY14) for purchase incentives and charging infrastructure development*
Pricing structure for EV charging	*The charging infrastructure is largely developed under the public-private partnership mode* *i. ToU tariff by utilities* *ii. Hook up fee and per min plan* *iii. Free charging* *iv. Monthly memberships*
Impact on Grid	*Utilities had been making investments in grid upgradation and modernization to absorb renewable energy. Advanced EV charging hubs are integrating local solar power, energy storage and dynamic pricing to manage EV demand on the grid*
EV Population	*i. Over 150,000 electric vehicles in the current fleet* *ii. Over 40,000 charging stations (more than fuel filling stations)*

Table 8: Overview of Japan EV program

2.2 EV Grid Integration Pilots

Electricity distribution companies across the world have played a pro-active role in development of EV ecosystems. Utilities offer discounted electricity prices for EV charging, especially to encourage grid-friendly charging. Time-of-day tariffs are used as price signals to promote off-peak charging. Besides, utilities in US, Japan and China are experimenting with utilization of EVs as grid asset either by using them as demand response resource or for providing ancillary services through Vehicle-to-Grid technologies. This study documents the following EV grid integration pilots that have been undertaken by utilities or are currently underway:

i. **SDG&E Application VGI Rate Pilot, California** (San Diego Gas & Electric, 2014)**:** This was designed to expand access to EV charging stations and collect data on the ability of different pricing structures to impact charging times. It was approved by the California Public Utilities Commission in January 2016 and is scheduled to last four years. Specific measures include:

   - **EV charging station construction in multi-unit dwellings**: SDG&E proposed to build 3,500 charging installations in a mix of workplace and multi-unit dwellings. These new charging stations will also provide data for the rest of the project.
   - **Data collection on price signals' impact on charging behavior**: SDG&E has developed a variable Vehicle Grid Integration (VGI) Pilot Rate for EV owners, which will display hourly differences in electricity rates on a day-ahead basis, reflecting different grid conditions. Customers can view these rates on the VGI Pilot Program smart phone application or website and plan their charging accordingly. The data collected from the pilot will be utilized to understand how it affects charging behavior and grid utilization.

ii. **BMW i ChargeForward Program, California** (Boeriu, 2015)**,** (Pacific Gas and Electric, 2015)**,** (BMW, 2016)**:** The BMW i ChargeForward program is a joint program between vehicle manufacturer BMW and California utility Pacific Gas & Electric (PG&E) Company. BMW served as an aggregator allowing the EVs of its consumers to act as a resource for PG&E's DR program. The specific actions taken by BMW include:

   - BMW allowed 100 owners of BMW i3 EVs to sign up for its initial 18-month program. During periods of high demand, the participants received alerts through a smartphone app asking them to delay charging of their EV. If accepted, software in the charging equipment allows BMW to halt the charging remotely. Participants were paid USD 1,000 up-front (in the form of a BMW gift card) as well as additional payments depending on how many charging delays they accept.
   - Utilization of retired EV batteries: BMW provided "second life" EV batteries from its EV demonstration vehicles, which served as stationary storage. These batteries can also provide grid balancing for absorbing intermittent renewable energies.

iii. **Grid integration pilot at Los Angeles Air base, California, US:** Los Angeles Air Force Base (LAAFB) is a non-flying United States Air Force Base located in El Segundo, California. A proof-of-concept for demonstrating that battery storage of Plug-in Electric Vehicle (PEV) fleets can provide energy and ancillary services to the CAISO markets to generate additional revenues has been undertaken at the base. The project was started in February 2012 and intends to demonstrate retail peak shaving for the Air Force Base as well as the demonstration of providing wholesale service as a Non-Generating

Resource (NGR) providing ancillary services. The fleet has 42 vehicles, with 34 vehicles having V2G capability with 655 kW instantaneous demand or capacity (Southern California Edison, 2016)

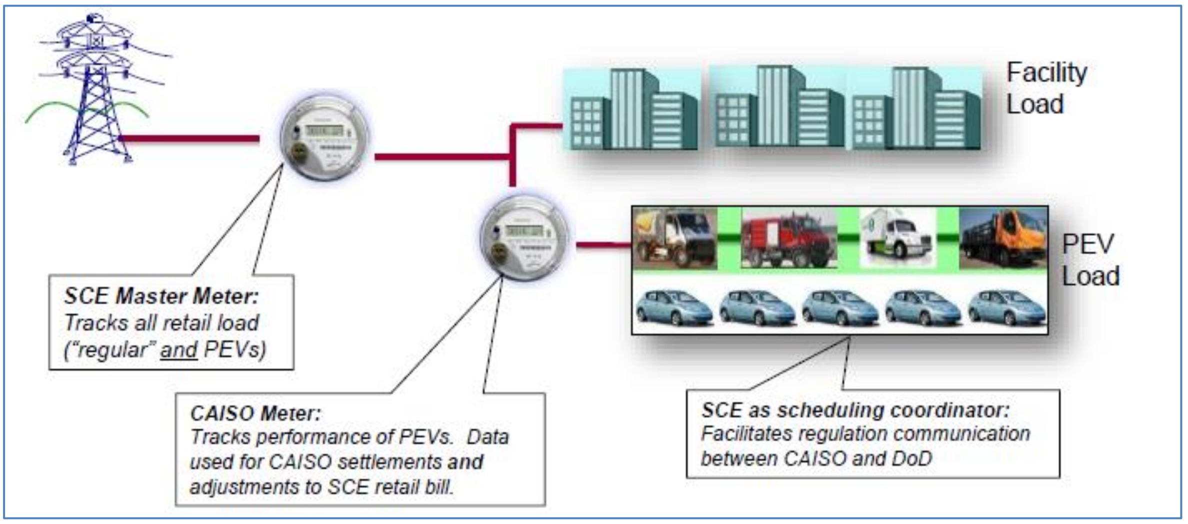


Figure 2: LAAFB Project layout

iv. **Enel and Nissan V2G pilot, UK**: Integrated energy company Enel and Japanese car manufacturer Nissan partnered to develop an energy management solution that uses a Vehicle-to-Grid (V2G) recharging device which allows car owners as well as energy users to operate as individual "energy hubs" – able to draw, store and return electricity to the grid, thus providing grid balancing services. Under the UK pilot, 100 V2G units would be installed and connected at locations agreed by private and fleet owners of Nissan LEAF and the e-NV200 electric vans. This will enable customers to connect and recharge electric cars when energy cost is at its lowest while using the electricity stored in their car batteries at any time, releasing the rest back into the network, with a reasonable economic return.

v. **ZEM2All Project, Spain:** Zero Emission Mobility to All (ZEM2ALL) Project in Malaga (Spain) was a result of an agreement signed in Japan between Endesa and Mitsubishi Corporation, under the Spanish-Japanese collaboration JSIP (Japan Spain Innovation Program). The four-year project, which ended on February 2016, was designed to assess the usage patterns of electric vehicle on a day-to-day basis and aimed to develop a new energy management model in large cities, taking maximum advantage of the modern technologies of e-mobility and smart electric infrastructure. The project comprised 200 EVs (Nissan Leafs & Mitsubishi iMiEV). It featured 220 conventional charging points and 23 CHAdeMO DC fast charging points including 6 bidirectional chargers capable of providing V2G functionalities. The EVs would support the integration of intermittent renewable sources by absorbing the excess power produced by the RES (Renewable Energy Source) and supply back to the grid at the times of peak demand (i.e. V2G). The project has accounted for 4.6 million kilometers with zero emissions, more than 100,000 charges and the prevention of 330 ton of CO2 emissions (Endesa, 2016).

vi. **EDISON Project, Denmark**: The EDISON project was developed by IBM, DONG energy, the regional energy company of Oestkraft, Technical University of Denmark, Siemens, Eurisco, and the Danish Energy Association. The project successfully demonstrated optimal system solutions for EV integration including network issues, market solutions and integration of high levels of variable renewable energy into the Danish power grid. The project explored using an aggregator (fleet operator) to aggregate the consumption of several EVs and handle their interaction with the grid as one single unit, which gives the EVs an opportunity to participate in the electricity market. To demonstrate this, an Edison EV Virtual Power Plant (EVPP) was developed. EVPP was the resulting server-side management system containing analytics technology and featuring standards based interfaces to DERs and grid stakeholders. These EVPPs took on the role of Fleet Operators (FO) for individual EVs in real-time coordinating their charging in private homes, company parking lots and at charging stations. Besides the development of "Intelligent Charging", research was also conducted to gain more knowledge of battery technology and understanding various charging schemes that could influence battery lifetime. Laboratory tests showed that with adequate knowledge of the batteries and BMS, intelligent charging schemes can be performed without any negative influence on the battery lifetime. The project recommended development of standardization for fast deployment of EVs.

vii. **Jeju Island Smart Grid Test-Bed, South Korea**: The Jeju Smart Grid Test-bed is located at Gujwa-eup in the northeastern part of Jeju Island, where wind farms were already in operation. The pilot project was implemented from December 2009 through May 2013 (Jeju Government, 2009).

- Government funding and partnership with industry: During the implementation period, USD 248 million were invested into the pilot, of which USD 76 million came from the government and the rest from the private sector. A total of 186 companies in different sectors participated in the pilot, forming 12 consortiums to focus on different areas.
- Integration of five focus areas: Smart Place, Smart Transportation, Smart Renewable, Smart Power Grid, Smart Electricity Service were identified.
- High EV penetration and corresponding charging infrastructure development in Jeju.
- Impacts of the pilot:
  - Establishment of infrastructure for integrating EVs, DR, and renewable energy.
  - Relevant technologies verified for application, and new business models explored successfully.
  - V2G successfully tested for the first time in Korea.
  - EVs, DR, and renewable energy integration given priority for immediate application and scale-up in the project expansion phase.

2.2.1 Designing Effective Rate Structures to Shift EV Charging Times using Demand Response

Electric vehicles are clearly an additional source of revenue for electricity distribution companies and with proper planning, can result in more efficient and less costly operation of the grid. EVs will also provide ancillary services, lower electricity prices for ratepayers and facilitate greater integration of renewable energy resources. EVs can offer the dual benefit of RE integration as well as load flattening for discoms. EVs are a "flexible load," i.e. their charging times can be coordinated with renewable energy generation, to ensure effective uptake of RE in the grid thus allowing discoms to meet their RPOs as well as for load flattening.

A study, modeling this type of approach, concluded that based on expected renewable energy penetration in California by 2030, this type of demand-side management (DSM) could reduce oversupply of renewable energy by up to 72.6%. The impact was also substantial (albeit slightly lower) for Germany, which was predicted to reduce oversupply by 64% (Dallinger, Schubert, & Wietschel, 2012). Discoms can adopt tariff structures to influence electric vehicle charging behavior and grid impacts. Most commonly used structures are:

i. **Time-of-use rates,** offering lower electricity prices during off-peak hours. ToU prices are already widely used in multiple states and countries, including California, New York, Maryland in USA, and in Germany. NV Energy, Nevada offers ToU rates having wide differentials for on and off-peak power. Its summertime rate for northern Nevada varies from 40.7 cents/kWh for on-peak power (from 1 pm to 6 pm) and to 5.53 cents/kWh for off-peak power (from 10 pm to 6 am). In Europe, EDF in France offers an off-peak discount. A special EV TOU rate is offered by RWE in Germany. A day/night tariff is offered by EON in Germany. An U.S. Department of Energy-funded program concluded that consumers in California are willing to shift their EV charging time to off-peak hours based on the ToD incentives (DOE, 2013).

ii. **Real-time pricing (RTP) tariff** dynamically sets prices based on the real-time marginal cost of energy. Although electricity tariffs provide indirect control of EV charging, detailed analyses of such schemes are scant (Sioshansi, 2012). Utilities of Illinois i.e. ComEd and Ameren offer real-time pricing programs in Illinois (Galvin Power, 2016). For RTP, enabling technologies (e.g., smart meters) are usually required to support the accuracy of measurements. The reason RTP relies highly on enabling technologies is that it should be closely connected with wholesale market prices, as well as with consumer feedbacks (two-way communication required) (Hu, Kim, Wang, & Byrne, 2015). Nova Scotia Power, Canada offers one part Real Time Pricing (RTP) to customers who have loads of 2,000 KVA or 1,800 KW and above. The consumers are charged based on the company's actual hourly marginal energy costs, plus the fixed cost for on-peak and off-peak usage (Nova Scotia Power, 2016).

   Experience with such dynamic pricing arrangements for electric vehicle charging is still limited, and ongoing changes in technology, including the systems used to control charging, contribute to uncertainties about how dynamic pricing will affect charging behavior.

iii. **Day-ahead hourly rate** provides dynamic hourly rates for EV charging on a day-ahead basis. It allows the user to know optimum hours for charging his vehicle and gives the flexibility to minimize the charging cost predictably and reliably. This structure is being tested by San Diego Gas and Electric (SDG&E). However, one disadvantage of this structure would be that the customers may not be comfortable with the complexity of dynamic pricing, in which case aggregators will be needed to aggregate the load and obtain the benefits of dynamic pricing (Fitzgerald, Nelder, & Newcomb).

iv. **Managing the load through direct control:** In this approach, charging loads could be controlled directly by grid operators, discoms or aggregators of charging infrastructure within the defined parameters set by the user. This would give the flexibility to avoid overloading the distribution network and optimize all assets on the grid under a dynamic pricing regime. However, it would be infrastructure intensive and require Advanced Metering Infrastructure (AMI) to measure hourly or sub-hourly demand to enable billing for dynamic pricing. It would also require a high degree of communication between the network operators, aggregators, distribution licensees, and the users (Fitzgerald, Nelder, & Newcomb).

A study conducted in Spain observed that ToU, CPP and RTP pricing succeeded in shifting charging times to the off-peak periods, given the hypothetical penetration of EVs based on EU target rates of EV adoption in 2030. However, system congestion was observed due to large numbers of EV owners scheduling their vehicle charging for the start of a low-price period (Cruz-Zambrano, et al., 2011).

To manage system congestion, Southern California Edison, a Californian utility, offered a service of programming the 'end-time' for EV charging. This technology, already available in many EVs, allows a utility to stagger the load from EV charging throughout the off-peak periods. It was found to be useful in minimizing the impact of EVs on grid functioning (Southern California Edison, 2013).

2.3 International Business Models for Investment in Public Charging Infrastructure

Predominantly three types of business models are being used worldwide for investment in EV charging infrastructure.

2.3.1 Manufacturer or Business Owner Funding:

A large business that benefits from EV sales and usage (such as an automaker or a battery supplier), or that seeks to gain a marketing advantage (such as a retail or restaurant chain) could contribute funding to subsidize the deployment of DC fast charging network for inter-regional EV travel. It happens either through the manufacturer's own investment in developing infrastructure, or by availing service of a third-party provider.

a. Own installations

i. Tesla built a network of fast-charging Superchargers along highways throughout North America, Europe, and Asia, which are available to Roadster, Model S, and Model X owners for free. Tesla has built over 5,400 Superchargers and around 9,000 Destination Charging connectors similar to Tesla Wall Connectors, for the current population of 200,000 vehicle owners. It plans to double the network to 10,000 Superchargers and 15,000 Destination Charging connectors around the world.

ii. 400 kWh Supercharger credits are awarded annually to the users, after which they are charged based on either per kWh or per minute.

b. Partnering with service providers

i. **BMW Chargenow:** BMW partnered with ChargePoint, to allow its users to access the ChargePoint's network through a smart card.

ii. **Nissan No-Charge to Charge Supported by EVGo:** Two years of complimentary public DC fast and Level 2 charging at participating stations

2.3.2 Private Sector Charging Service Providers:

Private sector players sell their hardware to the host (either lease or monthly EMIs) develop infrastructure and take a share of the revenue from charging events. e.g. ChargePoint, EVGo, CarCharging, Volta

a. ChargePoint – The company designs, builds and supports all the technology, from charging station hardware to energy management software to a mobile app and provides mainly Level 2 Chargers conforming to SAE standards. It does not own the station but provides the hardware and the software for charger installations for the hosts with fixed payments aligned to usage. The host is free to set the tariff for charging of EVs. Users uses smart cards to pay for charging on the mobile app, which is remitted to the hosts. It has built a network of more than 35,800 charging spots across North America. The company raises investments from private investors, manufacturers and avails tax credit and the subsidies provided by Government.

b. **EVGo –** EVGo network of charging stations were initially installed by NRG Energy (Utility), but was later sold to Colorado-based sustainable-energy investment firm Vision Ridge Partners. It works with automakers to develop charging stations and installs, operates and maintain its own fast charging network. EVGo has the largest network of fast charging stations in US, it operated around 900 fast charging stations in addition to the individual charging stations at homes, and other retail outlets our growing network.

The different charging plans are designed based on the need of the users (Table 9). It can also be installed at business and retailers premises. The chargers conform to CHADeMO and CCS standards. The company also partners with discoms to expand the network.

Table 9: EV charging plans of EVGo

	DC Fast	Level 2 (Plug-ins)	FLEX (Low usage)
Monthly Fee	USD 14.95	USD 5.95	None
DC Fast	10 cents / min.	10 cents / min.	USD 4.95 session + 20 cents /min.
Level 2	USD 1.00 / hr.	USD 1.00 / hr.	USD 1.50 / hr.
Contract Term	12 months	12 months	month-to-month
Setup Fee	None	None	USD 4.95
Early Termination	USD 29	USD 29	None

c. **Volta –** It installs EV chargers which are free for usage for EV drivers and free for host for installation. The company leverages advertising revenues. It has installed around 300 charging stations across US.

2.3.3 Utility Funded Installations:

Distribution licensees install EVSE as a part of their business and get the budget approved from the Commission as a part of their annual budget (PGE, SDGE, SCE). The utility either provides tariff incentives to the users or aggregate the EV installation and appoint a service provider to provide standardized chargers to the consumers.

a. **Tariff incentives for EV users:** EV users are offered rebates if they have a separate connection for EV charging. The charger is installed and maintained by the hosts. The rate structure of different discoms is provided in Annexure II.

b. **Discoms aggregating the EV installation and appointing third party service providers:** Utility invites RFP for installation and maintenance and empanels a few vendors. Hosts can choose from the list of selected vendors for installation. The Host also gets federal rebates for installation of chargers. Utility installs and maintains the EV service connection and electrical infrastructure, the tariff structure for charging is decided by Commission and the investment is recovered through the tariffs socialized across the consumer base. A few pilots have been approved by CPUC for PG&E, SDG&E and SCE. The programs are in support of the Zero-Emission Vehicle goals. A summary of the approved programs is given in following table:

Table 10: Summary of approved programs for Californian Discoms

	SDG&E	PG&E	SCE
Scope	Up to 3,500 L1 & L2 at 350 sites over 3 years	7,500 L2 100 DCFC over 3 years	At least 1,250 L1 & L2 in at least 12 months
Approved budget (USD)	45 million	160 million	22 million
Ownership of the charger	SDG&E owned	PG&E owned	Site host owned
Incentive	10% of average EVSE cost for Multi-unit dwellings (MUDs), 20% for workplaces Fee waived for Disadvantaged Communities, government, school, non-profit, small business and affordable housing sites	10% of EVSE cost for MUDs, 20% for private businesses; Fee waived for Disadvantaged Communities, government, and non-profit sites	Site host buys equipment 25-50% rebate from SCE 100% rebate for Disadvantaged Communities
Rates/Pricing	Choice of VGI rate to driver or to site host	Choice of commercial TOU rate to driver or to site host	Site host pays commercial rate, site host sets Pricing
Load Management	VGI rate reflects grid conditions; if site host takes rate, must submit load management tactics	TOU rate reflects grid conditions; if site host takes rate, must submit load management tactics Develop DR program within 3 years	Evaluate load management strategies in Pilot Phase Develop DR program within 3 years
Site Host Recruitment	SDG&E + 3rd party partners	PG&E + 3rd party partners	SCE + 3rd party partners

Battery swapping is another model that is being tried by manufacturers and third-party service providers. A battery swapping (or switching) station is a place where a vehicle's discharged battery or battery pack can be immediately swapped for a fully charged one, eliminating the waiting period for charging the vehicle's battery. In recent years, Better Place, Tesla Motors and Mitsubishi Heavy Industries have used this business model. Here is an overview of some of the players involved:

a. **Voltia:** Formerly Greenway Operator, Voltia, designs and runs proprietary battery swapping stations (BSS) in Slovakia for switching the batteries in light commercial vehicles. The stations have been in successful commercial operation since 2012.
b. **BAIC:** A subsidiary of Beijing Automotive Group (BAIC Group) has installed few battery-switch stations for EV taxi in Beijing on November 2016. The company plans to rapidly expand its network of battery swapping stations.
c. **Better Place:** Better Place launched its first battery-swapping station in Israel, in Kiryat Ekron, near Rehovot in March 2011. However, owing to the lower than expected penetration of EVs, the company went bankrupt.

d. **Tesla Motors:** Tesla Motors designed its Model S to allow fast battery swapping in June 2013, and announced a plan for global deployment. However, the company currently is not pursuing its original plan which was also subjugated by supercharging stations for Model S electric car drivers.

2.4 Key takeaways from international experience

The EV market is quickly growing, and many discoms are pro-actively adapting to and supporting electric vehicle adoption. Around the world, electricity distribution companies have built electric vehicle charging networks to build consumer range confidence and created programs to minimize grid impacts. High penetration of electric vehicles will be a new source of electricity sales and offer new business opportunities. Many electricity distribution companies and governments have worked proactively to study the impacts of electric vehicles on the grid and the best ways to integrate them in a grid-friendly manner. The following key lessons can be abstracted from the case studies:

- Substantial fiscal incentives are the most important driver of EV uptake. However, fiscal incentives need to be supplemented by developing consumer awareness.
- Availability of charging infrastructure is another prerequisite for electric mobility because it helps overcome range anxiety. Countries with dense public charging infrastructure have higher EV market shares.
- **Electricity distribution companies have a key role to play in development of charging infrastructure and establishing clear pricing policies for charging.**
- **Regulators in regulated electricity markets have directed or mandated electricity distribution companies to invest in EV charging infrastructure. CPUC and PSB, Vermont have approved the capital expenditure against EVSE installation under their annual budgets.**
- Public private partnerships have been successful in deployment of infrastructure, supplementing the consumer awareness efforts as well as providing independent incentives to the consumers.

Chapter 3: Technical Impact Assessment of EVs on the Grid

This chapter assesses the technical impact of EV charging on the distribution system. At the national level, the penetration of 5 – 6 million EVs is likely to require no more than 5000 MW of additional capacity, which would be equivalent to approximately 1.5% of the total current installed capacity (more than 330 GW as on 31 July 2017). Hence the impact of EVs on the grid at the national level is expected to be negligible. This chapter focuses on the impact of EVs on the distribution feeders at the local level as there may be certain pockets with high concentration of EVs charging coincident with the system peaks. This chapter is divided into the following sub-sections:

- Selection of modeling software platform used
- Description of the basic model and modifications made to develop a near real-life scenario and associated assumptions
- Results and Inference
- Conclusions and recommendations.

3.1 Selection of a simulation platform

The aim of this technical assessment is to understand the effect of electric vehicle integration into the distribution grid, under different penetration levels at the distribution feeder levels. We compared three common modelling tools used to assess the impact of loads on grids.

PLEXOS: PLEXOS is a power system model which focuses on power generation and provides technical as well temporal detail. It can be used to forecast electricity market prices, analyze market power, analyze production costs, resource operations, quantify fuel requirements and air emissions. However, it only focuses on modelling the prices based on economic trends.

GridLAB-D™ is a power distribution system simulation and analysis tool, coupled with distribution automation models and software integration tools. It can be used to create and validate rate structures, examine consumer reaction and verify the interaction and dependence of programs with other technologies and wholesale markets. However, it is not very user friendly and has not been widely used for EV simulation studies.

Matlab/Simulink: Matlab is a programming language and computing environment which uses specialized data types to integrate computation, visualization, and programming in familiar mathematical notation. Simulink is a graphical programming environment for modelling, simulating and analyzing multi-domain dynamic systems. **Matlab/Simulink has been widely used by researchers to study the impact of EVs on the grid and hence, it has been used in the current study to understand the interaction of EVs with local distribution transformers.**

3.2 Details of the Matlab Model

The model used for the assessment was taken from a library on the MATLAB directory. The network layout available in the Matlab directory is shown in figure 3.

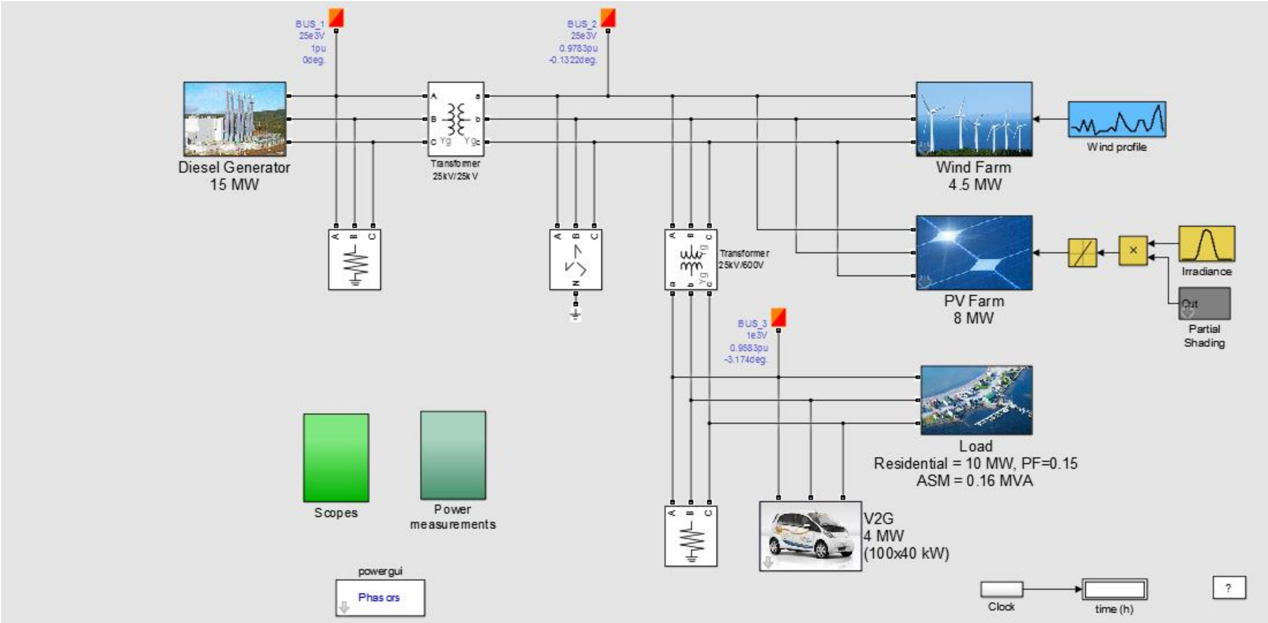


Figure 3: Layout of the model from Matlab Library

The library model consists of three major components: generating stations (Solar PV farm, Wind farm and Diesel generator), the distribution lines and two 3-phase transformers and Loads (electrical vehicle and residential load).

1. **Generating stations:** The system consists of three electricity generating sources with a total installed capacity of 27.5 MW
2. **3-phase transformers and distribution network:** Transformer A (25kV/25kV)(substation transformer),connected to the generating sources. Transformer B (25kV/600V) connected to Transformer A, which relays the electricity to the residential and electric vehicle module
3. **Loads**: Baseline residential and EV load.

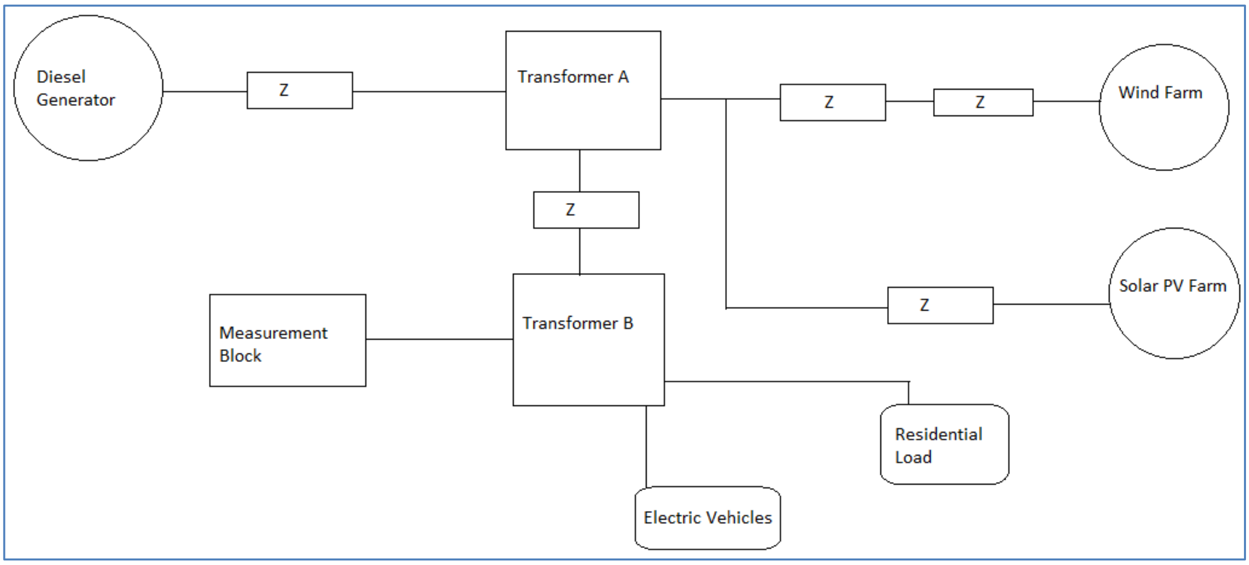
3.3 Model Customisation

The available model exemplified to accommodate real-life loads and impedences as shown in figure 4. Network scenario we used has the following components:

1. **Generating stations:** The electricity generation sources have been kept the same as in library model. However, the capacities have been varied for different scenarios.
2. **3-phase transformers and distribution network:** Line impedances[26] were added between the line between generating station and Transformer A as well as on the input side of Transformer B.

[26] Transmission lines have an inherent property to oppose current flow, thereby leading to losses and heat generation which is called impedance. This opposing force is due to line properties such as resistance, inductance and capacitance. In short transmission lines (lengths < 80 kms), there are negligible current leakages due to the high quality of conductor used in the distribution system. Using Matlab-Simulink, impedance block operators were introduced into the model. These blocks require

3. **Impedance Blocks**: The impedance block was added from Simulink library to account for network impedances seen in real-life distribution networks.
4. **Loads**: Baseline residential and EV load
   i. **Residential Load Module:** The residential load module is connected to a transformer that provides electricity supply at 600 V. The module has an initial power factor of 0.95 with a load size of 10 MW. The residential block has provisions for changing the load size and power factor as required. However in this study, the power factor is kept constant.
   ii. **Electric Vehicle Module:** The electric vehicle module taken from the MatLab directory represents 100 cars. The library module also has the provision, similar to the residential block, to change the motor and battery capacity as well as the number of cars. The electric vehicle module from the directory includes 5 sub-modules, each representing a particular charging and usage pattern. The sub-modules available from the library are listed below with the number of cars mentioned in brackets.
      a) **Type A:** People going to work with the possibility of charging the car at work plus night charging at home (25 cars).
      b) **Type B**: People going to work with the possibility of charging the car at work, with a longer driving distance, compared to Type A, plus night charging at home (35 cars).
      c) **Type C**: People going to work but have no possibility of charging the car at work, implying charging at home only (10 cars).
      d) **Type D**: People staying at home and have their cars connected to the grid at all time (20 cars).
      e) **Type E**: People working in the night shift and charge their cars during the day (10 cars).



**Z: impedance blocks*

Figure 4: Line diagram of the altered model for simulation

5. **Measurement Block:** Modelling results for baseline and other cases are reported at Transformer B (shown as Measurement Block in Figure 4).

---

inductance and resistance input parameters. Given the rigidity of the model, impedance blocks were added in locations that would not eventually fail the simulation.

3.4 Assumptions made in the model

As described in the previous section, modelling exercise made a few specific changes to reflect real-life scenarios. These changes included introduction of impedance and state-of-charge. These assumptions are described below.

i. Impedance values: To represent a system of varying sizes, two different set of inductance and resistance input parameters were considered as given in following table. Values related to inductance and resistance reported as "input values" for two Sets are calculated in the model using a standard formulation described in Annexure IV

Location	Set 1		Set 2	
Impedance Block	Distance	Input values	Distance	Input values
Diesel to Transformer A	1 Km	I: 5*10^-4 R: 0.06	5 km	I: 2.5*10^-3 R: 0.3
Solar PV to Transformer A	5 Km	I: 2.5*10^-3 R: 0.3	10 km	I: 7.5*10^-3 R: 0.9
Wind to Transformer A	5 Km	I: 2.5*10^-3 R: 0.3	25 km	I: 7.5*10^-3 + 5*10^-3 R: 0.9 + 0.6
Transformer A to Transformer B		-	5 km	I: 2.5*10^-3 R: 0.3

Table 11: Input values for inductance (I) and resistance (R)

a. Set 1 represents a small network where RE generators are located within 5 kms and diesel generator is located within 1 km from the point of demand
b. Set 2 represents a more realistic scenario where generators are located at different points with Wind generator placed at a maximum of 25 kms away from the load. Additional line impedance was considered between the two transformers to account for all impedances from lines.

ii. State of Charge (SoC): A battery's SoC is dependent on a variety of factors ranging from human behavior (range anxiety), vehicle handling characteristics, distance travelled, age of the battery, charging times to name a few. The following features were implemented:

a. In each of the Sub-modules, the cars discharge to 20% SoC, at least once during the day except **Type D**
b. The boundary conditions for the battery charging are assumed to be within the range of 90% and 20% SOC.

3.5 Case and Scenario Development for Analysis

3.5.1. Residential Feeder

In order to conduct distinctive assessment of the impact of electric vehicles on a distribution network, three cases were developed with two different system sizes. The model characteristics for each case are presented in the following table with a description given below the table.

Case / Scenarios	Case 1 Slow Charging	Case 2 Fast DC Charging	Case 3 Fast DC Charging	Case 4 Fast DC Charging
Impedance	Impedance values from set 2	-	Impedance values from set 1	Impedance values from set 2
Baseline	Residential Load (10 MW)	Residential load (10 MW)	Residential load (10 MW)	Varying EV and Residential Loads
Scenario 1	Baseline Load + 0.66 MW EV load (24 kWh battery capacity) (100 cars)	Baseline Load + 4 MW EV load (85 kWh battery capacity)	Baseline Load + 4 MW EV load (85 kWh battery capacity)	
Scenario 2	Baseline Load + 0.66 MW EV load (85 kWh battery capacity) (100 cars)	Baseline Load + 8 MW EV load (85 kWh battery capacity)	Baseline Load + 8 MW EV load (85 kWh battery capacity)	
Scenario 3	Baseline Load + 1.32 MW EV load (24 kWh battery capacity) (200 cars)	Baseline Load + 8 MW EV load (24 kWh battery capacity)	Baseline Load + 8 MW EV load (24 kWh battery capacity)	
Scenario 4	Baseline Load + 1.32 MW EV load (85 kWh battery capacity) (200 cars)	Baseline Load + 4 MW EV load (24 kWh battery capacity)	Baseline Load + 4 MW EV load (24 kWh battery capacity)	
Scenario 5 (Peak coincident charging)		-	Baseline Load + 4 MW EV load (85 kWh battery capacity)	

Table 12: Case and Scenarios analysed

Case 1

This case was introduced to assess the impact on the transformer due to slow charging. Under this case, the residential load was kept constant at 10 MW and the charger was assumed to have a rated power of 6.6 kW, corresponding to a Nissan Leaf on-board charger. Following scenarios were developed

i. **Baseline Scenario**: wherein the model is simulated with a base residential load only.
ii. **Scenario 1**: An electric vehicle load of 0.66 MW (6.6 kW and 100 vehicles) and with a battery capacity of 24 kWh is added.
iii. **Scenario 2**: An electric vehicle load of 0.66 MW (6.6 kW and 100 vehicles) and with a battery capacity of 85 kWh is added.
iv. **Scenario 3**: An electric vehicle load of 1.32 MW (6.6 kW and 200 vehicles) and with a battery capacity of 24 kWh is added.
v. **Scenario 4**: An electric vehicle load of 1.32 MW (6.6 kW and 200 vehicles) and with a battery capacity of 85 kWh is added.

Under all cases and scenarios, the system is simulated to reproduce results relevant for a period of 24 hours.

Case 2 and **Case 3**

While simulating the model under **Case 2** and **Case 3**, the residential load was kept constant at 10 MW. The rating of EV charger and battery capacities were varied, which formed the basis for various scenario. The starting rated capcity was considered to be 40kW and was subsequently increased in steps of 40 kW. Similarly, the battery capacity was altered to gauge the impact of battery size variations on the grid.

i. **Baseline Scenario**: wherein the model is simulated with a base residential load only.
ii. **Scenario 1**: An electric vehicle load of 4 MW (40 kW and 100 vehicles) and with a battery capacity of 85 kWh is added.
iii. **Scenario 2**: An electric vehicle load of 8 MW (80 kW and 100 vehicles) and with a battery capacity of 85 kWh is added.
iv. **Scenario 3**: An electric vehicle load of 8 MW (80 kW and 100 vehicles) and with a battery capacity of 24 kWh is added.
v. **Scenario 4**: An electric vehicle load of 4 MW (40 kW and 100 vehicles) and with a battery capacity of 24 kWh is added.
vi. **Scenario 5**: In the model, the residential load peaks between 5 pm to 9 pm. To ascertain the performance characteristics of the transformer, the electric vehicle block is modified, where all cars are made to start and finish charging between 5 pm and 9 pm, so that the EV charging coincides with the residential peaking. This scenario was simulated to understand the impact on transformer during peak co-incident charging conditions.

Case 4

In the model, there are two major load modules; residential and electric vehicle load. Both module load sizes were varied and the impact studied. The details about the load size choices will be given under the results.

3.5.2. Commercial Feeder

In the next step of the assessment, the impact of electric vehicles on a commercial distribution network is assessed. The load module was modified to represent a commercial load profile. The load curve peaks at 12 noon with a over 95% of the total load acting on the transformer. The sub-profiles of the EV modules was retained as the same in the case of residential load assessment.

The commercial load was also simulated for two power ratings of 6.6 kW and 40 kW with two different battery capacities of 24 kWh and 85 kWh.

Cases / Scenario	Case 1 (No Impedance)	Case 2 (Set 1 Impedance)
Baseline	Commercial Load (10 MW)	Commercial Load (10 MW)
Scenario 6	Baseline + EV load (4 MW 85 kWh)	Baseline + EV load (4 MW 85 kWh)
Scenario 7		Baseline + EV load (0.66 MW 24 kWh)
Scenario 8		Baseline + EV load (0.66 MW 85 kWh)

Table 13: Developed Scenarios for assessment

3.6 Results

3.6.1. Results for Case 1 (Slow Charging)

Under this simulation, the residential load was kept constant at 10 MW and EVs were assumed to be charging through a slow charging EV Charger (6.6 kW).

The following results were obtained:

Case 4 (Baseline)	Residential Load (10 MW)
Voltage (V)	530.14
Current (x10^4 amps)	1.648
Maximum Demand (MW)	8.74

Table 14: Voltage, current and demand experienced by transformer under Case 1

Case 1	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	EV load (24 kWh battery, 100 cars)	EV load (85 kWh battery, 100 cars)	EV load (24 kWh battery, 200 cars)	EV load (85 kWh battery, 200 cars)
Rating of the charger (kW)	6.6	6.6	1.32	1.32
Voltage (V)	530.07	530.13	530.17	530.13
Current x10^4 (A)	1.648	1.65	1.66	1.676
Maximum Demand (MW)	8.73	8.75	8.80	8.88
Voltage Drop (%)	0.013%	0.002%	-0.006%	0.002%
Rise in Max. Demand (%)	-0.08%	0.15%	0.72%	1.64%

*Table 15: Voltage, current and demand experienced by transformer after addition of EV load under **Case 1***

Inference

- On simulating the model, it was noted that the residential load had a major impact on the transformer, when the model was limited to 100 cars.
- On increasing the number of cars to 200, the electric vehicle load impacts the peak experienced by the transformer.
- It is noted that the transformer is not adversely impacted by the lower power rating or by the increase in number of vehicles.

3.6.2. Results for Case 2 & Case 3 (fast charging)

As mentioned earlier, with scenarios for Case 2 and Case 3 being similar, the simulation results and conclusions have been presented together.

3.6.2.1. Baseline Scenario:

On Simulink, the model is reviewed and simulated with a residential load size of 10 MW. In Case 3, the impedance values are included into the model and the system is simulated to generate the following results.

Parameters	Residential load(Case 2)	Residential Load (Case 3)
Voltage (V)	552.34	550.33
Current (x10^4 amps)	1.58	1.58
Maximum Demand (MW)	8.73	8.70

Table 16: Maximum Voltage, current and demand experienced by transformer for Baseline Scenario for Case 2 and 3

3.6.2.2. Scenario 1, 2, 3, 4

Following the simulation of the **baseline scenario**, the electric vehicle module of 4 MW with 85 kWh battery capacity is added and the system is simulated **(Scenario 1)**. Subsequently, **Scenario 2**, **3** and **4** were simulated to present a more discerning picture on the influence of varying battery sizes on the transformer.

	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Residential + EV Load **(Case 2)**	Residential + EV Load **(Case 3)**	Residential +EV Load **(Case 2)**	Residential +EV Load **(Case 3)**	Residential + EV Load **(Case 2)**	Residential + EV Load **(Case 3)**	Residential + EV Load **(Case 2)**	Residential + EV Load **(Case 3)**
Voltage (V)	542.56	541.45	540.17	539.25	540.84	540.23	542.75	542.07
Current (Amps x10^4)	1.868	1.81	2.25	2.191	2.2	2.175	1.805	1.78
Maximum Demand Power (MW)	10.13	9.80	12.15	11.81	11.89	11.75	9.79	9.64
Increase in Max demand (MW)	1.40	1.10	3.42	3.11	3.16	3.05	1.06	0.94

Table 17: Voltage, current and demand experienced by transformer for Scenario 1, 2, 3, 4

	Voltage Drop		Increase in Maximum Demand	
	Case 2 (without impedance)	**Case 3 (with impedance)**	**Case 2 (without impedance)**	**Case 3 (with impedance)**
Scenario 1	1.70%	1.60%	16%	13%
Scenario 2	2.20%	2.00%	39%	36%
Scenario 3	2.20%	1.80%	36%	35%
Scenario 4	1.70%	1.50%	12%	11%

Table 18: % Voltage drops and increase in Maximum Demand across scenarios compared to the baseline scenario

3.6.2.3. Scenario 5 for Case 2

This scenario was assessed to understand the impact of co-incident peak charging of EVs on the transformer and the results are reported in following table.

Scenario5		
	Residential (Peak) + EV (4 MW)	**Residential (Peak) + EV (3.2 MW)[#]**
Voltage (V)	485.8	512.07
Current (Amps x10^4)	2.48	2.2
Maximum Demand (MW)	12.05	11.27
Voltage Drop (%)	11.7%	6.953%
Increase in Max. Demand (MW, %)	3.35 (38.6%)	2.57 (29.56%)

Table 19: Voltage, current and demand experienced by transformer for Scenario 5

Inference

From the simulations, it can be seen:

- There is an increase in current supplied from **Transformer B** across all scenarios, due to the EV load.
- With the addition of the EV module, the current drawn from the transformer and the voltage drop increases due to EV charging requirements. The transformer does not experience heavy transients.
- While comparing the result with the impedance model, the influence of impedance on the transformer is discernable, although the variation is not drastic.
- The introduction of impedance brings about a substantial change in voltage drops experienced by the transformer; specifically in scenarios with same load size but different battery capacities. (i.e. **Scenario 1** and **4**; **Scenario 2** and **3**).
- The current drawn in **Scenario 1** and **2** (**85 kWh battery scenarios**) have larger peaks with flat plateaus[27], while **Scenario 3** and **4 (24 kWh battery scenarios**) show pointed peaks with lower current drawl. This is because the batteries would reach full charge (~0.9 SoC) faster in a 24 kWh than for an 85-kWh battery.
- The battery size does not have a major impact on the transformer. The difference in current drawn across scenarios with different battery capacities and same load size, are shown below:

Current Drop	Case 1	Case 2
Between Scenario 1 and Scenario 4	3%	1.6%
Between Scenario 2 and Scenario 3	2.2%	0.7%

Table 20: Current drawl variations for different battery capacities

- For **Scenario 5**, the **voltage drop** is estimated to be **11.7%**, when the transformer experiences higher loading particularly in the later part of the day, with the full EV load modeled to begin charging in the evening which is beyond the allowed limits of voltage fluctuations. Simulation with 3.2 MW EV fast charging load observes a drop of 6.7-6.9% when compared to the Case 2 baseline scenario. Although, it is a bit higher than the prescribed threshold under the grid code; any load below 3 MW would not lead to a change in voltage by over 6%.

[27] Annexure IV includes voltage and current profiles as graphs

3.6.3. Results for Case 4

In this case, the model was simulated with varying load sizes. The electric vehicle load was varied from 4 MW to 20 MW and the residential load was varied from 4 MW to 20 MW. *(However, the simulations failed beyond 12 MW of Residential load and 16 MW of EV load and hence are not presented in Table 21).* A test simulation was conducted with a residential load of 10 MW and the voltage drops in relative terms were simultaneously noted.

			Residential Load (MW)		
			4	8	12
Electric Vehicle Load (MW)	0	Voltage (V)	576.02	547.86	517.45
		Current (I)	0.62*10^4	1.28*10^4	1.95*10^4
		Maximum Demand (MW)	3.57	7.01	10.09
	4	Voltage (V)	573.79	545.31	505.17
		Current (I)	0.845*10^4	1.49*10^4	2.26*10^4
		Maximum Demand (MW)	4.84	8.12	11.41
	8	Voltage (V)	569.13	537.38	491.36
		Current (I)	1.16*10^4	1.77*10^4	2.6*10^4
		Maximum Demand (MW)	6.60	9.51	12.77
	12	Voltage (V)	562.64	527.74	472.5
		Current (I)	1.52*10^4	2.09*10^4	3.015*10^4
		Maximum Demand (MW)	8.55	11.02	14.24
	16	Voltage (V)	557.99	518.8	451.9
		Current (I)	1.62*10^4	2.23*10^4	3.39*10^4
		Maximum Demand (MW)	9.03	11.55	15.31

Table 21: Voltage, current and demand experienced by transformer under Case 4

		Voltage Drop			Increase in Maximum Demand		
Residential Load ->		4	8	12	4	8	12
Electric Vehicle Load (MW)	4	1.036%	0.465%	2.374%	36%	16%	13%
	8	1.196%	1.913%	5.043%	85%	36%	27%
	12	2.323%	3.672%	8.688%	139%	57%	41%
	16	3.130%	5.304%	12.669%	153%	65%	52%

Table 22: Percentage Voltage drops and rise in maximum demand under ***Case 4***

Inference

- An increase in the residential load has a bigger impact on voltage drop in **Transformer B** than an increase in electric vehicle load as shown in Table 22.
- When simulations were conducted for loads exceeding 12 MW (for both components), there were many transients present, especially during peak hours and hence, it is preferable to have load sizes lower than 12 MW (>60%). EV load can be absorbed in a ratio of 2:3 of EV load to baseline load under 60% baseline load.
- In case of higher loading, proportion of electric vehicle load has lesser impact on voltage drop than residential load.

3.6.4. Results for Commercial Feeder

3.6.4.1. Results for Baseline and Scenario 6

The model was simulated with a commercial load of 10 MW and subsequently an electric vehicle load of 4 MW (40 kW rated capacity charger – Fast charger) was added. On simulating the commercial load, the following results were observed:

Parameters	Case 1	Case 2
Voltage (V)	553.58	553.21
Current x10^4 (A)	1.6	1.58
Maximum Demand (MW)	8.86	8.74

Table 23: Maximum Voltage, current and demand experienced by transformer for Baseline Scenario

Parameters	Case 1 + EV	Case 2+ EV
Voltage (V)	550.03	549.54
Current x10^4 (A)	2.195	1.95
Maximum Demand (MW)	12.07	10.72
Drop in Voltage (V)	0.64%	0.66%
Increase in Max. Demand (MW)	3.22, 36%	1.98, 23%

Table 24: Maximum Voltage, current and demand experienced by transformer after addition of EV load (fast charging) under Scenario 6

Inference

- The voltage drop increases marginally for **Scenario 6** in **case 1** and **case 2** respectively.
- There is a considerable increase in current drawn from the transformer, although the voltage variation is not drastic.

3.6.4.2. Results for Scenario 7 and Scenario 8 (slow charging)

In this scenario, the power rating of the charger was reduced to 6.6 kW, simiar to case 4 under the residential section.

Parameters	Scenario 7	Scenario 8
Voltage (V)	550.13	550.13
Current x10^4 (A)	1.61	1.61
Maximum Demand (MW)	8.855	8.855
Drop in Voltage (V)	0.56%	0.56%
Increase in Max. Demand (MW, %)	0.11, 1.31%	0.11, 1.31%

Table 25: Maximum Voltage, current and demand experienced by transformer after addition of EV load (slow charging) under Scenario 7 and 8

Inference

- On reducing the rated power of the chargers, the peak power exerted onto the transformer reduces.
- The voltage drop experienced by the transformer is around **0.5%**, when compared to the baseline.
- The transformer does not experience any transients for all scenarios.
- As expected, the impact of EV on the transformer is more discernible with fast charging.

3.7 Conclusions and Recommendations

- The 20 MVA transformer can be expected to handle the addition of an electric vehicle load up to **8MW with a baseline load of 10 MW in a residential feeder** as shown by **Case 2** and **Case 3**.
- For a constant residential load of 10 MW, the voltage drop ranges from **1.5%** to **2.2%**. **Allowed variation as per the conditions of supply for low voltage is +6% to -6%.**

Voltage Drop	Case 1 (without impedance)	Case 2 (with impedance)
Baseline	0%	0%
Scenario 1	1.70%	1.60%
Scenario 2	2.20%	2.00%
Scenario 3	2.20%	1.80%
Scenario 4	1.70%	1.50%

Table 26: Voltage drops across scenarios compared to the baseline scenario (Case 1 and Case 2)

- Beyond **90%** as vindicated by peak transformer loading under **Scenario 5,** transients occur and it is recommended to lower the exposure of a transformer to long transient periods.
- For the assumed input conditions, under **Case 4** a safe operating zone as highlighted in green is recommended.

		Voltage Drop		
Residential Load ->		4	8	12
Electric Vehicle Load (MW)	4	1.036%	0.465%	2.374%
	8	1.196%	1.913%	5.043%
	12	2.323%	3.672%	8.688%
	16	3.130%	5.304%	12.669%

*Table 27: Voltage drops for each scenario under **Case 4, Residential feeder***

- In case, when a **new transformer** system is being set up for an upcoming residential area, the transformer can be safely loaded with **a split of 60%-40%** for **electric vehicle and residential loads** respectively.
- If individual **electric vehicle and residential load sizes are lower than 50% of the transformer capacity**, then a split **of 50%-50% from electric vehicles and residential buildings** can be connected to the transformer.
- However, as observed from the peak coincident scenario with a 50% baseline load any load below 3 MW (around 20%) would not lead to a change in voltage by over 6%.
- For a commercial feeder, with a baseline load of 50% an additional 20% of EV load can be safely added.

- Slow charging does not have any adverse impact on the transformers for both the feeders

3.8 Limitations of the simulations

Although, much effort has been made to cover every aspect associated with the impact that the EVs can have on the local distribution network, the model has following limitations:

- This model is designed on an existing Matlab model, making it a rigid model, with little room for flexibility or changes. Several simulations failed when radical changes were made and hence left little room for flexibility.
- Assumption and other values considered are approximate estimates and it is recommended a detailed study on the transformer loading profile be done by relevant authorities before integrating electric vehicles.
- The instantaneous load on the transformer or high residential load could be different from a real case scenario. The unsystematic nature of these influencing variables compounds to the difficulty in quantifying the accurate load demand exerted by electric vehicles on the grid.
- The distances assumed while computing the inductance and resistance of lines would vary from a real case scenario.

Chapter 4: Legal Aspects and Possible Business Models

EV charging business essentially involves the use of electricity. Hence, the purview of the Electricity Act, 2003 (The Act) needs to be evaluated to understand if the EV charging business would be governed by provisions of The Act. Following propositions need to be considered in this regard:

i. Is the activity of EV charging covered in the definition of "electricity" in Sec.2(23)?

> *"(23) "electricity" means electrical energy-*
>
> *(a) generated, transmitted, supplied or traded for any purpose; or*
>
> *(b) used for any purpose except the transmission of a message;"*

Conclusion drawn: This implies that the EV charging activity qualifies as sale of electricity

ii. Would setting up of EV charging infrastructure deemed to be "electricity system as defined. in Sec 2(20), (25) & (40), produced below and who should control this "electricity system"?

> *"(20) "electric line" means any line which is used for carrying electricity for any purpose and includes*
>
> *(a) any support for any such line, that is to say, any structure, tower, pole or other thing in, on, by or from which any such line is, or may be, supported, carried or suspended; and*
>
> *(b) any apparatus connected to any such line for the purpose of carrying electricity;"*
>
> *"(25) "electricity system" means a system under the control of a generating company or licensee, as the case may be, having one or more -*
>
> *(a) generating stations; or*
>
> *(b) transmission lines; or*
>
> *(c) electric lines and sub-stations;*
>
> *and when used in the context"*
>
> *"(40) " line" means any wire, cable, tube, pipe, insulator, conductor or other similar thing (including its casing or coating) which is designed or adapted for use in carrying electricity and includes any line which surrounds or supports, or is surrounded or supported by or is installed in close proximity to, or is supported, carried or suspended in association with, any such line;"*

Conclusion drawn: This implies that the EV charging infrastructure qualifies as "electricity line" or "electricity system"

iii. Would EV charging stations fall within the definition of "works" as defined in Sec 2(77)

> *"**works <u>includes</u>** <u>electric line</u>, and any b<u>uilding, plant</u>, <u>machinery, apparatus</u> and <u>any other thing of whatever description</u> required to transmit, distribute or <u>supply electricity</u> to <u>the public</u> and to carry into effect the objects of a license or sanction granted under this Act or any other law for the time being in force."*

Conclusion drawn: EV charging stations are used to "supply electricity to the public". As such, the EV charging stations would fall under the definition of "works"

iv. Does this activity of providing EV charging services, entail "Supply" as defined under Section 2(70) of The Act?

"Supply", in relation to Electricity means the sale of Electricity to the licensee or consumer;

Conclusion drawn: EV charging would qualify as "resale" or "sale of electricity". As such, this would get included under the definition of "supply"

v. Would electric vehicles be treated as consumers as defined under Section 2(15) and would electric vehicle charging station fall within the meaning of "premises" or "structure" as defined under Section 2(51) or fall within the enlarged inclusive scope of the words "includes"?

*"(15) "consumer" means any person who is supplied with **electricity for his own use** by a licensee or the Government or by any other person engaged in the business of supplying electricity to the public under this Act or any other law for the time being in force **and includes** any person whose **premises** are for the time being connected for the purpose of receiving electricity with the works of a licensee, the Government or such other person, as the case may be;"*

*"premises" includes any land, **building** or **structure**.*

Conclusion drawn: EVs are supplied electricity for their own use; EVs get connected to the grid for the purspose of receiving electricity, which qualify the EVs as "consumers"

vi. Would the charging station fall within the meaning of "Distribution system" as in Section 2 (19)?

"(19) "distribution system" means the system of wires and associated facilities between the delivery points on the transmission lines or the generating station connection and the point of connection to the installation of the consumers;"

Conclusion drawn: As EVs are defined as consumers drawing electricity from the network, the EV charging stations qualify as "distribution system"

vii. Can the charging station receive electricity in bulk at single point from the distribution licensee, and thereafter engage in the activity of supplying electricity to vehicle owners? Would this amount to "sub-distribution"?

Conclusion drawn: The MoP Rules only allow sub-distribution for Co-operative Group Housing Societies. As the EV Charging Stations are not a part of sub-distribution for Co-operative Group Housing Societies and distribution of electricity is a licensed activity, the charging infrastructure needs to be an authorized activity by a licensee or to be carried out by the incumbent licensee

viii. Can EV charging stations be treated as open access consumers and Can the activity of supplying electricity to vehicle owners be done by a "franchisee" as defined in Sec 2(27)?

"(27) "franchisee means a person authorised by a distribution licensee to distribute electricity on its behalf in a particular area within his area of supply;"

Conclusion drawn: Any arrangement within the perview of the meaning of a "franchisee" would be allowed.

Summary of conclusions:

i. Evaluation of the above propositions, within the context of The Act, suggests that provision of EV charging service to EV users/drivers entails supply of electricity and hence would fall within the ambit of electricity distribution which is a licensed activity and hence, within the jurisdiction of the distribution utility.

ii. Through appropriate amendments in the The Act, the resale of electricity by any intermediary EV charging infrastructure operators can be allowed. Such amendments would need additions of specific provisos in licensing conditions.

iii. In the interim, within current ambit of The Act, following business models are possible:

   a. Distribution licensee-owned EV charging infrastructure
   b. Distribution licensee franchised EV charging infrastructure including public-private partnerships
   c. Privately-owned battery swapping stations

As a part of this study, **Draft Franchisee Agreement** to be signed between the distribution licensee and third parties was developed and included as Annexure V**.**

Details of business models that can be undertaken by various entities are given in figure 5.

Distribution Licensee-owned EV charging infrastructure

- Supply of electricity to vehicle owners would be part of the activities of the Distribution Licensee
- The retail supply tariff for supplying to the electric vehicle owners will be determined by the SERC

Distribution Licensee franchised EV charging infrastructure

- Utility can authorize a third party (Franchisee) to install and/or operate charging stations on its behalf in its area of supply. The franchisee can also be a public private partnership (PPP)
- Charging stations can receive electricity at a single point as bulk supply. The single point supply tariff as well as the tariff cap for retail sale will be determined by the SERC
- Franchisee can be allowed to purchase power through open access without applying Cross Subsidy Surcharge

Privately-owned battery swapping stations

- Utility, its distribution franchisee or any other third party can aggregate the demand for batteries and set up battery swapping stations
- Battery swapping will not amount to electricty resale and hence third parties can set up the stations with intimation to the Distribution Licensee to avail special category tariff.
- The Charging Station can receive electricity in bulk at single point from a distribution licensee or through open access to charge the batteries, as per provisions of the Act
- The bulk supply tariff/single point supply tariff will be determined by the SERC

Figure 5: Business models for EV charging infrastructure

The pros and cons of the above mentioned models is given in the following table:

Table 28: Pros and Cons of the suggested business models

	Investor	O&M Responsibility	Risks	Scalability	Tariff Structure	Financial support accessibility	Ability to adopt new technology
Distribution licensee-owned EV charging infrastructure	Distribution licensees	Distribution Licensee could opt to appoint a third party operator	None, as they are passed on to the consumers	Low	SERC will set tariffs (variable)	Low	Low
Distribution licensee franchised EV charging infrastructure including public-private partnership	Franchisee	Franchisee	Franchisee	Medium	Pre-agreed tariff cap	High	High
Privately-owned battery swapping stations	Third Party / Private player	Third party /private investors and operators	Third Party / Private player	Medium	With or Without Pre-agreed tariff cap	High; can attract private equity or partner with battery manufacturers for support	High

Chapter 5: Economic Impact Assessment of EVs

Infrastructure created to facilitate the EVs can be set up in two ways: (1) Direct investment by the distribution licensees and (2) Investement by the appointed franchisees of the distribution licensees. The third scenario described in Chapter 4 relates to an aggregator model.

This Chapter details the impact of investments made in the above-mentioned models and is organised in the following manner: details the tariff-setting philosophy and the methodology used, Section 5.2 details the scenarios and all the assumptions used in the current analysis, Section 5.3 reports the results from the model runs and the tariff impacts; and lastly, Section 5.4 shows possible tariffs related to a few DISCOMs with a special EV charging tariff.

5.1 Tariff setting principles

Based on the study of available regulations on the process for tariff-setting, it is clear that as the investments are expected to be made by distribution licensees, Multi-year Tariff Regulations relevant to distribution licensees need to be used as guiding principles. MERC MYT Regulations 2015 have been used here, for the purpose of determining the tariff impact. As per the regulations, the tariffs are determined for two separate businesses – one for the wires business and the other for retail supply business. Tariff impact calculated here pertains to the wires business of a distribution licensee as this investment pertains to creating EV charging infrastructure. Specific guiding financial principles used in our analysis are listed below.

- Debt: equity ratio is assumed as 70:30
- As per the regulations, capital costs considered for calculations include expenditure incurred during the construction and financing charges associated during the construction. In case any financial support is received for the project, the same shall be excluded from the capital cost to determine the debt: equity ratio. As such, any incentive offered either by the Department of Heavy Industries or by Ministry of Power would be deducted in the calculations. *However, the current analysis assumes no incentives by DHI or MOP and the capital costs are considered as the cost of the EV infrastructure.*
- Return on equity related to wires business of the distribution licensee is considered as 15.5%
- Depreciation value base is taken on the entire original capital cost; depreciated at 5.28% using straight line method up to 70% of the value base; thereafter, remaining value is depreciated at equal rate spread over remaining useful life (15 years is assumed as the useful life of the charger)
- Repayment of loan is- considered from the first year of commercial operation and is equal to the annual depreciation allowed.
- As per the regulations, interest on loan shall be the weighted average rate of interest computed on the basis of actual loan portfolio of the Discom; no moratorium is allowed. *The calculations in this report include value base and interest rate structure only for EV charging infrastructure investments.*
- Interest on working capital is recommended in the Regulations at base rate + 150 basis points. The working capital is calculated as operation and maintenance expenses for one month, maintenance spares at 1% of the Goss Fixed Assets and one-and-a-half months of expected revenue for use of distribution wires at prevailing tariff. W*orking capital has not been reckoned in this analysis.*
- As per regulations, components for ARR include the following a) O&M expenses, b) Depreciation, c) Interest of loan capital, d) Interest of working capital, e) Interest of deposits from consumers and

distribution system users, f) Provision for bad and doubtful debts, g) Contribution to contingency reserves, h) Return of equity capital, i) Income tax ***minus*** j) not tariff income and k) Income from other businesses. *The analysis includes items at a), b) and c) as indicated above.*

Tariffs are calculated as a summation of the following:

- Wheeling charges related to investments in the EV charging infrastructure (incremental)
- Current (or existing) wheeling charges
- Energy charges
- Cross subsidy surcharge in case of open access

5.2 Scenarios presented and corresponding assumptions

For public charging infrastructure[28], it is assumed that Level 2 and DC fast chargers would be installed in public places while Level 1 would be used for domestic installations only. Hence, tariff impact assessment is carried out for investment in Level 2 and DC fast chargers. The investment in Public Charging Infrastructure is assessed under two scenarios.

- National Electric Mobility Mission Plan (NEMMP) 2020 targets – NEMMP proposes around 5 million BEVs by 2020. NEMMP targets talk about a range of EV saturation. The analysis uses the bounds of the numbers as “Low growth” and “High growth” options.
- NEMMP+ (Aggressive targets beyond NEMMP-2020) – assumes an aggressive growth in electric public transportation modes specifically buses, in line with the stated objective of Ministry of Power. Similar to the NEMMP scenario, two possibilities identified as “Low growth” and “High growth” are used. This scenario assumes high growth in buses and target is considered as 10% of the existing bus fleet replacement by electric buses in the high growth option.

5.2.1. NEMMP scenario

Table 29 below summarizes the vehicle stock according to the NEMMP document.

Table 29: Vehicle stock as per NEMMP-2020 document

Category	Vehicle Stock		Source
	Low Growth	High Growth	
4 Wheelers	1,70,000	3,20,000	Table #29 at page number 133 of NEMMP 2020 document
2 Wheelers	48,00,000	48,00,000	
Buses	300	700	
3 Wheelers	20,000	30,000	
Light Commercial Vehicles	30,000	50,000	

Low growth and High growth sum up to 5 million and 5.2 million vehicles. It is worth noting predominance of 2-wheelers in the Low and High growth scenarios. The analysis presented in the subsequent sections does not include investments in charging infrastructure for 2-wheelers and

[28] The charging infrastructure broadly includes level 1 terminals, level 2 terminals (fast chargers) and level 3 terminals (rapid chargers). The typical time taken for charging by these chargers is 6-8 hours, 3-4 hours and less than 30 minutes respectively. (page number 108 of NEMMP 2020 document)

associated energy use. 2-wheelers are excluded from the analysis as public charging stations are not needed for 2 –wheelers as those are charged using standard plug-in sockets used in residences.

NEMMP document has detailed charging infrastructure requirement with associated costs. Table 30 summarizes charging infrastructure numbers presented in NEMMP document related to Level 2 and Fast DC charging and associated investment requirements. Low growth and high growth scenarios correspond to INR 603 Crores and INR 834 Crores investments respectively.

Table 30: Charging Infrastructure as per NEMMP document

Category	Low Growth		High growth		Sources
	Level 2	Fast DC	Level 2	Fast DC	
4 Wheelers	35,000	17,000	45,000	23,000	Exhibit # 42 to # 49 at page 112 to 115 of NEMMP 2020 document
2 Wheelers	-	-	-	-	
Buses	60	30	100	50	
3 Wheelers	2,000	1,000	4,000	2,000	
Light Commercial Vehicles	4,000	2,000	5,000	3,000	
Sub Total	**41,060**	**20,030**	**54,100**	**28,050**	
Cost per charging installation, INR (all types except buses)	36,000	2,25,000	36,000	2,25,000	Footnotes at the above referred exhibits
Cost per charging installation, INR (buses)	4,50,000	10,00,000	4,50,000	10,00,000	
Total Cost, INR Crores	**150**	**453**	**199**	**635**	
Grand total (INR Crore)	**603**		**834**		

5.2.2. NEMMP+ scenario

This scenario is developed with higher vehicles stocks given the increased attention of the policy-makers towards EVs. Substantive differences between NEMMP and NEMMP+ scenario presented in Table 31 are – (i) doubled 4-wheeler; tripled light commercial vehicles and 3-wheeler stock and substantially higher penetration of EV buses. It is assumed that 10% of the current stock of buses operated by public transport undertakings would move to EV buses in the high growth scenario. Tariff impact spreadsheet model created in this study allows creating more scenarios.

Table 31: Vehicle stock in NEMMP+ scenario

Category	Vehicle Stock		Sources/Assumptions
	Low Growth	High growth	
4 Wheelers	3,20,000	4,00,000	As per MOP note
2 Wheelers	48,00,000	48,00,000	Number not changed as this category is not included in the tariff impact analysis
Buses	25,000	2,00,000	Low-growth number as per MOP note
3 Wheelers	60,000	90,000	Tripled the numbers compared to NEMMP given the focus on this category
Light Commercial Vehicles	90,000	1,50,000	Similar to the number used in the MOP note

Notes: MOP draft document shared with CERC includes the following numbers: 400,000 for 4-wheelers including taxicabs, 25,00 buses (considered here in the low-growth scenario). Numbers for LCV and 3-wheelers are similar to the assumption made in this scenario.

Table 32 presents EV charging infrastructure investment numbers based on assumptions related number of EV charging stations needed for specified stocks. Number of charging stations assumed in this analysis are extrapolated from the baseline NEMMP scenario.

Table 32: Charging Infrastructure required for NEMMP + scenario

Category	Low Growth		High growth		Sources
	Level 2	Fast DC	Level 2	Fast DC	
4 Wheelers	45,000	23,000	56,250	28,750	Calculations described in the Notes section
2 Wheelers	-	-	-	-	
Buses	5,000	2,500	40,000	20,000	
3 Wheelers	6,000	3,000	9,000	4,500	
Light Commercial Vehicles	12,000	6,000	20,000	10,000	
Sub Total	**68,000**	**34,500**	**1,25,250**	**63,250**	
Cost per charging installation, INR (all types except buses)	36,000	2,00,000	36,000	2,00,000	Target costs by industry players
Cost per charging installation, INR (buses)	2,50,000	6,00,000	2,50,000	6,00,000	
Total Cost, INR Crores	**352**	**790**	**1,307**	**2,065**	
Grand total (INR Crore)		**1,142**		**3,372**	

Notes:
For the Low growth scenario, ratio of chargers to the number of vehicles in the respective categories are used to come up with new number of chargers.
For High growth scenario, percentage increase in the vehicle stock compared to the low growth scenario times the number of charges in the respective categories has been used

Projected investment is around INR 1,100 Crores and INR 3,400 Crores in the Low and High growth scenarios respectively.

5.3 Tariff impact results for NEMMP and NEMMP+ scenarios

As described at the beginning of section 5.1, tariff impact analysis is carried out with stated procedures in the MYT Regulations. One key component of tariff impact analysis is the energy use values. Energy consumption by EVs is calculated using energy use numbers presented in the FAME guidelines included in March 2015 office memorandum of the DHI. Table 33 and Table 34 report the energy use numbers related to the NEMMP and NEMMP+ scenarios respectively[29].

[29] More details can be found in Annexure VI

Table 33: Annual electricity consumption from vehicle stock using public infrastructure under NEMMP

Category	Average Distance Travelled, km#	Electricity consumption, kWh/100km^	Electricity consumption, kWh/100km	Annual energy consumption, MkWh (MUs)	
				Low Growth	High growth
4 Wheelers	40,000	36	0.36	2,448	4,608
2 Wheelers	8,000	8	0.08	3,072	3,072
Buses	50,000	175	1.75	26	61
3 Wheelers	25,000	15	0.15	75	113
Light Commercial Vehicles	30,000	36	0.36	324	540
			Total with 2-wheelers	5,945	8,394
			Total without 2-wheelers	2,873	5,322

Notes:

#Average distance travelled are assumed based on interviews with the market players except for 4-wheelers. 4-wheelers' distance travelled number is assumed as a weighted average of the numbers mentioned in the MOP note. These numbers are 150 km/day for taxis and 50 km/day for other 4-wheelers. Weighted average works out to be 120 kms/day, which is multiplied by 330 days/year of travel

^Electricity consumption numbers are from Office Memorandum of Department of Heavy Industries dated 26 March 2015 (highest number of the range of values are considered here)

Table 34: Annual electricity consumption from vehicle stock using public infrastructure under NEMMP+

Category	Average Distance Travelled, km#	Electricity consumption, kWh/100km^	Electricity consumption, kWh/100km	Annual energy consumption, MkWh (MUs)	
				Low Growth	High growth
4 Wheelers	40,000	36	0.36	4,608	5,760
2 Wheelers	8,000	8	0.08	3,072	3,072
Buses	50,000	175	1.75	2,188	17,500
3 Wheelers	25,000	15	0.15	225	338
Light Commercial Vehicles	30,000	36	0.36	972	1,620
Total with 2-wheelers				11,065	28,290
Total without 2-wheelers				7,993	25,218

Notes:

#Average distance travelled are assumed based on interviews with the market players except for 4-wheelers. 4-wheelers' distance travelled number is assumed as a weighted average of the numbers mentioned in the MOP note. These numbers are 150 km/day for taxis and 50 km/day for other 4-wheelers. Weighted average works out to be 120 kms/day, which is multiplied by 330 days/year of travel

^Electricity consumption numbers are from Office Memorandum of Department of Heavy Industries dated 26 March 2015 (highest number of the range of values are considered here)

It is clear that the energy-use in the NEMMP scenario; 3 billion units and 5 billion units for Low and high growth stocks except for 2-wheelers respectively; increases substantially to approximately 8 billion units and 25 billion units in case of NEMMP+ scenario. These numbers correspond to 0.5% of national energy consumption (approximately 1 trillion kWh) in case of NEMMP scenario and 2.5% in case of NEMMP+ scenario.

Tariff impact scenarios were developed include two options:

- Investments made in the EV charging infrastructure socialized across all the electricity consumers in the country (total end-use energy consumption in India, reported as 1 trillion units reported in LGBR report of CEA for FY 2017-18), and
- Investments made in the EV charging infrastructure recovered only from EV users charging their vehicles using public charging infrastructure

Table 35: Model results for tariff impact

Scenario	Business models	Growth options	Tariff Impact (Rs./kWh)
NEMMP	Scenario 1A: Investments socialized to all the consumers	Low Growth	0.0007
		High Growth	0.0010
	Scenario 1B: Investments charged only to EV category sales	Low Growth	0.2810
		High Growth	0.2097
NEMMP+	Scenario 2A: Investments socialized to all the consumers	Low Growth	0.0013
		High Growth	0.0040
	Scenario 2B: Investments charged only to EV category sales	Low Growth	0.1912
		High Growth	0.1790

It is evident that the entire investment in the EV charging stations socialized to the entire consumer base in the country has very low impact on the retail electricity tariffs. In case of NEMMP low and high growth scenarios, the tariff impact is as low as Paise 0.07/kWh to Paise 0.1/kWh respectively. In case of NEMMP+ scenario, the low and high growth tariff impact is Paise 0.13/kWh to Paise 0.40/kWh respectively as higher investments are made to create charging infrastructure for public transportation (buses). All of above numbers increase substantially when the tariff impact is apportioned only to EV users.

5.4 Possible tariffs for special EV category

Except for Maharashtra and Delhi, none of the Regulatory commissions have set-up a separate EV charging category. EV tariff proposed in Maharashtra is same as that of the commercial sector tariff and a a flat rate of INR 5.50 per unit has been fixed for charging stations for e-rickshaw and e-vehicles by Delhi Electricty Regulatory Commission. In this report, two scenarios for tariffs are presented – one base tariff based on the tariff impact calculated earlier in this Chapter and possible Time-of-day tariff based on the ability of the EVs to use the stranded assets usually backed down during the night time. Both base and the TOD tariffs are demonstrated for MSEDCL.

Broader Tariff Principles were developed as a part of this study and have been included as Annexure VII.

5.4.1. Base tariffs

Table 36: Base Tariff for the EV category for MSEDCL as an example

#	Component	Category	NEMMP		NEMMP+	
			Highest incremental charges socialized across all consumers	Highest incremental charges with only EV consumers paying the charges	Highest incremental charges socialized across all consumers	Highest incremental charges with only EV consumers paying the charges
1	**Tariff impact as incremental wheeling charges, INR/kWh**		0.001	0.281	0.004	0.191
2a	**Current approved wheeling charges, INR/kWh**	HT	0.58	0.58	0.58	0.58
2b		LT	1.18	1.18	1.18	1.18
3a	**Weighted average Energy Charges, INR/kWh**	HT-PWW	5.6	5.6	5.6	5.6
3b		HT-other public services	9	9	9	9
3c		LT-PWW	4.44	4.44	4.44	4.44
3d		LT-other public services	7.29	7.29	7.29	7.29
4	**ACoS, INR/kWh**		6.36	6.36	6.36	6.36
5a	**Total charges at par with PWW, INR/kWh (=1+2a+3a)**	HT-PWW	**6.18**	**6.46**	**6.18**	**6.37**
5b	**Total charges at par with other services, INR/kWh (=1+2a+3b)**	HT-other public services	**9.58**	**9.86**	**9.58**	**9.77**
5c	**Total charges at par with PWW, INR/kWh (=1+2b+3c)**	LT-PWW	**5.62**	**5.90**	**5.62**	**5.81**
5d	**Total charges at par with other services, INR/kWh (=1+2b+3d)**	LT-other public services	**8.47**	**8.75**	**8.47**	**8.66**
6	**Total charges at ACoS, INR/kWh (=1+4)**		**6.36**	**6.64**	**6.36**	**6.55**

5.4.2. Time-of-Day (TOD) structures

Primary rationale for proposing TOD structure for EV charging is that most generation assets in the country are backed-down during the night lean period. EVs can utilize stranded assets, resulting in capitalizing fixed charges paid by the distribution licensees to generators. TOD structure takes in to account the following parameters:

- Backed down capacity
- Cost per MW paid for the backed-down capacity

Table 37: Stranded assets and fixed costs for MSEDCL

	Unit	FY 2016-17	Source
Back Down capacity (A)	MW	6,379	MSEDCL MYT order (case 48 of 2016)
Capacity Charges related to Back down (B)	INR Crore	3,988	
Capacity charges per MW (B*10/A)	INR Crore/ MW	0.625	

Penalty paid by the distribution licensee can be equated with the TOD incentives that can be offered to the special ctagory tariff. Table 38 shows calculations pertaining to MSEDCL and also proposes the maximum TOD incentive that can be offered based utilization of stranded assets and costs thereof.

Table 38: Computation of ToD incentives corresponding to usage of stranded assets for MSEDCL

		NEMMP	NEMMP+
Electricty consumed by EVs in MSEDCL area	MUs	532	2521.75
Capacity utilization factor	%	100%	100%
Annual hours*	hours	3650	3650
Maximum stranded capacity that can be utilised	MW	145.80	690.89
Total incentive to be offered to the EVs	INR Crore	91.15	431.93
Maximum ToD incentives	INR/kWh	1.71	1.71

Note: It is assumed that the investment and infrastructure in MSEDCL would 10% of the national level

Assuming night time charging period to be of 10 hours[30]

[30] Refer to Annexure VI

Chapter 6: Charging standards and Regulatory Provisions for Grid Interconnection

EV charging infrastructure gets connected to the grid through specific interconnection points either at the HT or LT levels. We studied the current interconnection norms that exist in India. The Indian Electricity Grid Code defines specifics of such interconnections detailed below.

6.1. Indian Electricity Grid Code

The Indian Electricity Grid Code (IEGC) describes the philosophy and responsibilities of planning and operating of Indian power system specified by the Central Electricity Regulatory Commission in accordance with sub section 1(h) of Section 79 of the Act. The IEGC mainly deals with Rules, Regulations, Guidelines and Standards to be followed by participants in the system to plan, maintain and operate the Power system in the most secure, economic and efficient manner, while facilitating healthy competition in Generation and Supply of electricity. IEGC basically brings together single set of Technical and Commercial Rules, encompassing all utilities connected to or using the Inter - State Transmission System (ISTS). The IEGC also includes functioning of NLDC, RLDCs, SLDCs and optimal maintenance planning of Generation/ Transmission facilities in the Grid. Scope of IEGC covers all users, SLDC, RLDC, NLDC, CEA, CTU, STU, Licenses, RPCs and Power Exchanges (major players in the Generation and Transmission business)

Even the Grid voltage limits (stated at Para 5.2S) of the IEGC indicate that all users, SLDC, RLDC, NLDC, CTU, STUs shall take all possible measures to ensure that Grid Voltage always remains within a given range (operating limits) for each voltage level.

Since EV charging is a load on the distribution system no modifications in IEGC (which basically covers Regulations for ISGS, ISTS and Load Despatch Stations etc.) is envisaged.

Our analysis shows that no specific modification in the IEGC are needed for EV charging.

6.2. Charging Standards

The Automotive Research Association of India (ARAI) has published the draft EV charging standards which heavily adapts from IEC and IS standards for EV Charging systems. The key features of the two standards are given below:

a) AIS 138 (Part 1): Electric vehicle conductive AC charging system
   - For charging electric road vehicles at standard AC supply voltages (as per IS 12360/IEC 60038) up to 1000 V and for providing electrical power for any additional services on the vehicle if required when connected to the supply network.
   - Applicable for
     - AC Slow Charging (230 V, 1 Phase, 15 A Outlet with connector IEC 60309)
     - AC Fast Charging (415 V, 3 Phase, 63 A Outlet with connector IEC 62196)
   - Operation within the range of ±10 % of the standard nominal voltage as per IS 12360 and within 50 Hz ± 3% range of frequency
   - Grid Communication protocol has not been finalized

- The charging system shall be designed to limit the introduction of harmonic, DC and non-sinusoidal currents
- EVSE Classification AC Slow A, B, C with Max. load of 1 kW, 2.2. kW, 3.3 kW and AC Fast A, B, C, D with Max. load of10 kW, 12 kW, 23 kW and 45 kW respectively. AC Fast Class B, C, D would need prior permission from the utility for installation

b) AIS 138 (Part 2): Electric vehicle conductive DC charging system

- The harmonic limits for the input current of the EVSE - DC, with no load connected, shall be in accordance with IEC 61000-3-2.
- Conducted disturbances emitted at the input of the EVSE - DC, with a resistive load at its rated output power, shall be less than the amplitude of the level defined in the standard

The Department of Heavy Industries has also released its report for public comments on standardization of public EV chargers on 15 May 2017. The report specifies the classification and provides detailed specifications for AC and DC public chargers.

6.3. BIS Standards

In order to standardize the EV charging standards in the country, the Bureau of Indian Standards have constituted an incumbent committee. ETD-51 standards are being set-up under the Chairmanship of an expert from the Department of Science & Technology. ETD-51 will attempt to finalize the EV Charger Standards on fast track by the end of calendar year 2017.

6.4. CEA plans

Under the Chairmanship of Member (Planning) - CEA, a electricity storage/battery storage Committee of Bureau of Indian Standards (BIS, ET 52) has been constituted. In addition to the ET52 process, CEA is constituting a Standing Committee with representations from Ministry of Transport, Department of Heavy Industries, Ministry of Urban Development, Director R&R (Ministry of Power), Power utilities, CERC, POSOCO, NCR-PB, DMRC, TERI and Advisor, MOP/MNRE to draft a framework for developing Charging Infrastructure. CEA is also exploring a long term approach for the charging arrangements to be designed for reverse feed into the grid from the electric vehicles. In this case the charged electric vehicles would be in a position to feed the power supply into the grid.

Chapter 7: Conclusions and Way forward

Technology development, fiscal incentives, innovative business models, and supportive policies have led to growth of Electric Vehicles (EVs) across the world. The Forum of Regulators commissioned a techno-economic study on the impact of electric vehicles on grid requirements and capacity and necessary framework to enable implementation thereto.

The following questions have been examined as part of this study:

(1) What are the international best practices for EV integration and promotion?

(2) What has been the role of regulators and distribution distribution licensees in the uptake of EVs?

(3) What would be the impact of EV load on the local distribution system?

(4) What business models can be developed for public charging infrastructure development in the context of the Electricity Act, 2003?

(5) What would be the tariff impact of a distribution utility's investment in public charging infrastructure?

7.1. Key findings and Recommendations

7.1.1. Technical impact on the Grid

Matlab simulations carried out in this study to model impact of electric vehicle integration into the distribution grid suggest no substantial impact on the grid voltages in residential, commercial and mixed feeders.

It is recommended that CEA notify additional standards for grid connectivity of public charging infrastructure.

7.1.2. Legal aspects and possible business models

As per provisions of the Electricity Act 2003 and its amendments thereof, the activities of charging of EVs amounts to supply of electricity. Suitable legal framework and in the interim a clear provision in the National Electricity Policy and/or Tariff Policy or the Rules would be desirable for enabling smooth deployment of EV infrastructure.

Three potential business models are proposed:

i. Direct by Discom- Discoms creating EV charging infrastructure through their own investment and selling electricity to EV owners;
ii. Franchise model- contractual agreement between Discoms and third parties, allowing EV charging infrastructure to be set-up by third-parties and resale of electricity to EV owners;
iii. Battery swapping stations- aggregation of demand through battery swapping stations.

7.1.3. Commercial aspects- tariff impacts

The study analyzes two primary scenarios

(i) NEMMP targets
(ii) (ii) Incrementing NEMMP targets with heavy emphasis on public transport especially buses, termed as NEMMP+.

i. Based on modelling of tariff impact, if charging infrastructure costs are socialized across the national electricity use, the impact on per-unit-basis is minimal. Alternatively, if the investment was to be paid for only by the EV consumers, still the incremental cost (over energy charges) is not significant.
ii. Time-of-Day (ToD) structure: several generating stations in the country are backed-down during the night time. Such backed down assets can be utilized for EV charging during the night, which can improve their PLF.

7.1.4. Policy and Regulatory interventions

Internationally, EVs have received substantial push from national policies and incentives put in place by the respective Governments. Regulators across North American markets have also allowed utility investments as tariff pass-through, given the system benefits of EVs.

Government of India had announced the National Electric Mobility Mission Plan 2020 (NEMMP) in 2012, along with Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME) guidelines in 2015 to provide incentives to EVs.

Whilst the Regulatory aspects will have to be dealt with by the Appropriate Commission, it would be advisable for the sake of uniformity and harmony of Regulations to have suitable provisions in the Tariff Policy or the Rules on the following interventions:

i. Regulators to allow pass through of investments made in EV charging infrastructure by the distribution licensees in tariffs
ii. Create simplified framework for franchise agreements between the distribution licensees and private sector/interested Public Sector Undertakings/associations for setting up public charging infrastructure
iii. Allow distribution licensees to appoint multiple and non-exclusive franchisees within its area of supply for setting up public charging infrastructure
iv. Create new tariff category for EVs by allowing recovery of incremental cost of infrastructure through wheeling charges over and above the average cost of service
v. Allow special ToD structure for EV charging infrastructure accounting for use of backed-down assets in the night time
vi. Allow Open Access to EV charging infrastructure/aggregators. Also allow banking of RE generation to promote reduced tariffs.
vii. In order to encourage that the demand created by EVs is also met from renewable energy sources either directly or by way of substitution, appropriate incentive mechanism should be designed for such consumption.

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Annexure I: List of Experts Contacted and Questionnaire Used

List of Experts Contacted

S. No.	Name	Designation	Organisation
1	Mr. Gopal Kartik	Head – Strategy and Business Planning	Mahindra Electric
2	Mr. Ketsu Zhang	Regional Director, General Manager of BYD INDIA	BYD, China
3	Geisha J Williams	President-Electric	Pacific Gas and Electric (PG&E)
4	Christian Stav	Chief Executive Officer	NTE Energy
5	Hyoungmi Kim	Senior Utility and Energy Efficiency Specialist	Natural Resources Defense Council, China
6	Prof. Willett Kempton	Professor, School of Marine Science and Policy	University of Delaware
7	Dr. Jasna Tomic	Director, Research Programs	University of Delaware
8	Dr. Hartmut Schmeck	Professor, Institute for Applied Informatics and Formal Description Methods (AIFB)	Karlsruher Institute of Technology
9	Dr. Christopher Cherry	Associate Professor, Civil and Environmental Engineering	University of Tennessee
10	Prof. Mukesh Singh	Assistant Professor	Thapar University
11	Rish Ghatikar	Scientist	EPRI
12	Chris Marnay	Scientist	LBNL
13	Doug Houseman	VP Technical Innovation	Enernex
14	Scott Fischer	Director, Market Development	EVGo
15	Dr. Ahmad Faruqui	Principal	The Brattle Group
16	Dr. Jurgen Weiss	Principal	The Brattle Group
17	Mr. David Roberts	Senior Advisor	Vermont Energy Investment Corporation

Questionnaire – Experience on management of EVs and its impact on the grid

Background

Government of India has formulated a scheme, titled Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India, under the National Electric Mobility Mission Plan 2020, to encourage the progressive induction of reliable, affordable and efficient electric and hybrid vehicles. Therefore, considerable growth is envisaged in the EVs market with greater adoption of EVs in India. It is also envisaged that greater adoption of EVs in India would have a considerable impact on the electric grid. The Forum of Regulators (FOR) (constituted by the Government of India in terms of Section 166 (2) of the Electricity Act, 2003) has thus commissioned a study for a detailed technical and economic assessment of the impact of electric vehicles on the grid. MP Ensystems is conducting the study on behalf of FOR which would feed into the model EV regulations for India.

In this regard, we are conducting a detailed review of the pilots and demonstration projects undertaken worldwide. Being an important stakeholder, we would appreciate if you could share your experiences. This would help us design and optimal policy for integration of EVs with the grid.

1. General Details of the project (please write about the location, participants, number of vehicles)
2. Technical details (Please specify the technical details of the vehicles used (make, model and type), software and hardware components used (battery management system, interconnection requirements),
3. Please describe the distribution system upgrades undertaken?
4. Please describe the communication and protection standards/protocol used?
5. Please describe the Metering and settlement mechanism
6. What was the role of utilities and the regulators?
7. What were the technical challenges faced in the project and the solutions identified/suggested?
8. What were the management challenges encountered and the solutions identified/suggested?
9. What was the total cost associated with the project? (vehicles, infrastructure upgrades, implementation and other associated costs)
10. Please describe the total system benefits realized?
11. Would you like to share the data on the impact of EVs charging on the local distribution grid profile?

Annexure II. Rate Structure for EV Charging by International electricty distribution companies

PGE Rate Structure for EV charging

Rate	Description	Total Energy Rates (USD per kWh)
EV-A (Non-tiered, Time-of-Use)	Single Meter: The price per kilowatt-hour varies depending on the time	**Summer Usage: Peak - USD 0.45389,** Part Peak - USD 0.24986, Off peak-USD 0.12225 Winter Usage: Peak-USD 0.32018, Part peak-USD 0.19794, Off peak-USD 0.12503
EV-B (Non-tiered, Time-of-Use)	Dual meters: The price for charging varies throughout the day. Your home energy use is measured separately	Summer Usage: Pe**ak - USD 0.44738, Part Peak - USD .24660,** Off peak-USD 0.12179 **Winter Usage: Peak-USD 0.31325,** Part peak-USD 0.19447, Off peak-USD 0.12453
E1 (Tiered)	Single meter. Costs are based on three usage tiers	Baseline Usage (USD /kWh) - 0.19979, 101% - 400% of Baseline - 0.27612, High Usage Over 400% of Baseline - 0.40139
Time-of-Use Rate Plan - 3-8 p.m. (ETOU-A)	Single meter. credit for all usage up to your baseline allowance	**Summer: Total Usage Peak USD 0.39336 O**ff-peak **- USD 0.31778** Baseline Credit: Peak - USD 0.08830, Off peak - USD 0.08830 Winter: Total Usage Peak - USD 0.27539, Off-peak - USD 0.26109 Baseline Credit: Peak - USD 0.08830, Off peak - USD 0.08830
Time-of-Use Rate Plan - 4-9 p.m. (ETOU-B)	Single meter. Prices are higher in the summer than in the winter	Summer: Peak - USD 0.36335, Off-peak - USD 0.26029 Winter: Peak - USD 0.22588, Off-Peak - USD 0.20708
E6 - (Tiered, Time-of-Use)	Single meter. The price per kilowatt-hour is based on the time and the amount of electricity used	Discontinued now

Peak: 2:00 p.m. to 9:00 p.m Monday through Friday. 3:00 p.m. to 7:00 p.m. Saturday, Sunday and Holidays. Partial-Peak: 7:00 a.m. to 2:00 p.m. and 9:00 p.m. to 11:00 p.m Monday through Friday, except holidays. Off-Peak: All other hours. The summer season is May 1 through October 31 and the winter season is November 1 through April 30

SDGE Rate Structure for EV charging

Summer - Electric Vehicle Time-of-Use Rate			
EV-TOU			
Rate	**On-Peak**	**Super Off-Peak**	**Off-Peak**
Time-of Day	Noon - 8:00 PM	Midnight – 5:00 AM	All other hours
Amount	USD 0.49	USD 0.19	USD 0.23
EV-TOU-2			
Rate	**On-Peak**	**Super Off-Peak**	**Off-Peak**
Time-of Day	Noon - 6:00 PM	Midnight – 5:00 AM	All other hours
Amount	USD 0.49	USD 0.19	USD 0.24
Winter - Electric Vehicle Time-of-Use Rate			
EV-TOU			
Rate	On-Peak	Super Off-Peak	Off-Peak
Time-of Day	Noon - 8:00 PM	Midnight – 5:00 AM	All other hours
Amount	USD 0.23	USD 0.20	USD 0.22
EV-TOU-2			
Rate	On-Peak	Super Off-Peak	Off-Peak
Time-of Day	Noon - 6:00 PM	Midnight – 5:00 AM	All other hours
Amount	USD 0.23	USD 0.20	USD 0.23

Summer rates are May through October. Winter rates are November through April. Rates valid as of 1/1/17.

SCE Rate Structure for EV charging

For separate EV meter	**Energy Charge -USD /kWh/Meter/Day**
Summer Season - On-Peak	0.16790
Off-Peak	0.09155
Winter Season - On-Peak	0.16790
Off-Peak	0.09155

XCEL Energy EV charging rate

Metering Set-Up	Monthly Charge	Off-Peak (9 p.m.– 9 a.m., holidays & weekends)	On-Peak (9:00:01 a.m.– 8:59:59 p.m., weekdays)
Separate Meter for the EV Only	USD 4.95	USD 0.033/kWh	USD 0.14170/kWh (other months) USD 0.17564/kWh (June–Sept.)

Annexure III: Key International Policies Implemented for Vehicle Grid Integration

Entity	Policy	Description & Relevance
FERC	Federal Energy Regulatory Commission Order No. 784*(Issued July 18, 2013*)	• Expands FERC 755 pay-for-performance requirements to account for speed and accuracy • Potentially affects payment for VGI services, depending on VGI capabilities
FERC	Federal Energy Regulatory Commission Order No. 792*(Issued November 22, 2013)*	• Adjusts the Small Generator Interconnection Procedures (SGIP) and Small Generator Interconnection Agreement (SGIA) for generating facilities no larger than 20 MW • Will shape interconnection associated with storage devices
ISO/IEC	Standard ISO/IEC 15118*(Stage 60.60: International Standard published as ofApril 16, 2013)*	• Creates a global standardization of communication interface • Will likely shape VGI enabling technologies
SAE	Standard SAE J1772 *(Most recent revision is October 15, 2012)*	• Establishes a recommended practice for EVSE • Will likely shape VGI enabling technologies
CPUC	Assembly Bill (AB) 2514 and CPUC Storage Proceeding Docket No. R. 10-12-007	• Sets targets for the procurement of storage • States that EV capacity can contribute to the storage procurement targets • Potentially creates demand for VGI services, depending on how VGI compares to other options
CPUC	Resource Adequacy (RA) Proceeding	• Guides the resource procurement process and promotes infrastructure investment by requiring LSEs to provide capacity as needed by California ISO • Potentially influences demand for VGI services, depending on VGI capability to meet RA needs.
CPUC	Demand Response (DR) Proceedings Docket No. R.07-01-041	• Reviews and analyses demand response to assess its potential role in meeting the state's energy needs • Potentially serves as a platform for clarifying rules about how EV may participate in DR
CPUC	Rule 24 DR Direct Participation	• Determines how customers might "directly participate" in, or bid services directly into, the wholesale market. • Potentially influences the process by which VGI services can offer wholesale market services.
CPUC	Rule 21 Interconnection and Net-metering (Docket No. R.11-09-011)	• Describes the interconnection, operating and metering requirements for generation facilities of various sizes to be connected to a utility's distribution system, over which the CPUC has jurisdiction. • May influence the interconnection requirements around VGI, where two-way power flows are possible
CPUC	Wholesale Distribution Access Tariff (Docket No. ER11-2977-000)	• Defines the tariffs architecture of energy transfer between California ISO and utilities or customers • Guides a portion of VGI payment processes
CPUC	EV Proceedings	• Addresses barriers to widespread EV adoption, on which the VGI market is dependent

Entity	Policy	Description & Relevance
		• Promotes communication among EV stakeholders, including those involved in VGI • Addresses EV sub-metering issues, which could influence VGI payment processes
	Smart Grid Proceeding (Docket No. R.08-12-009)	• Establishes standards, protocols, and policies which will affect Smart Grid • programs and strategies, such as VGI

CPUC framework for Vehicle grid integration

CPUC has developed a framework for Vehicle to grid integration (California ISO, 2014). CPUC has defined four Regulatory issues in EV integration as:

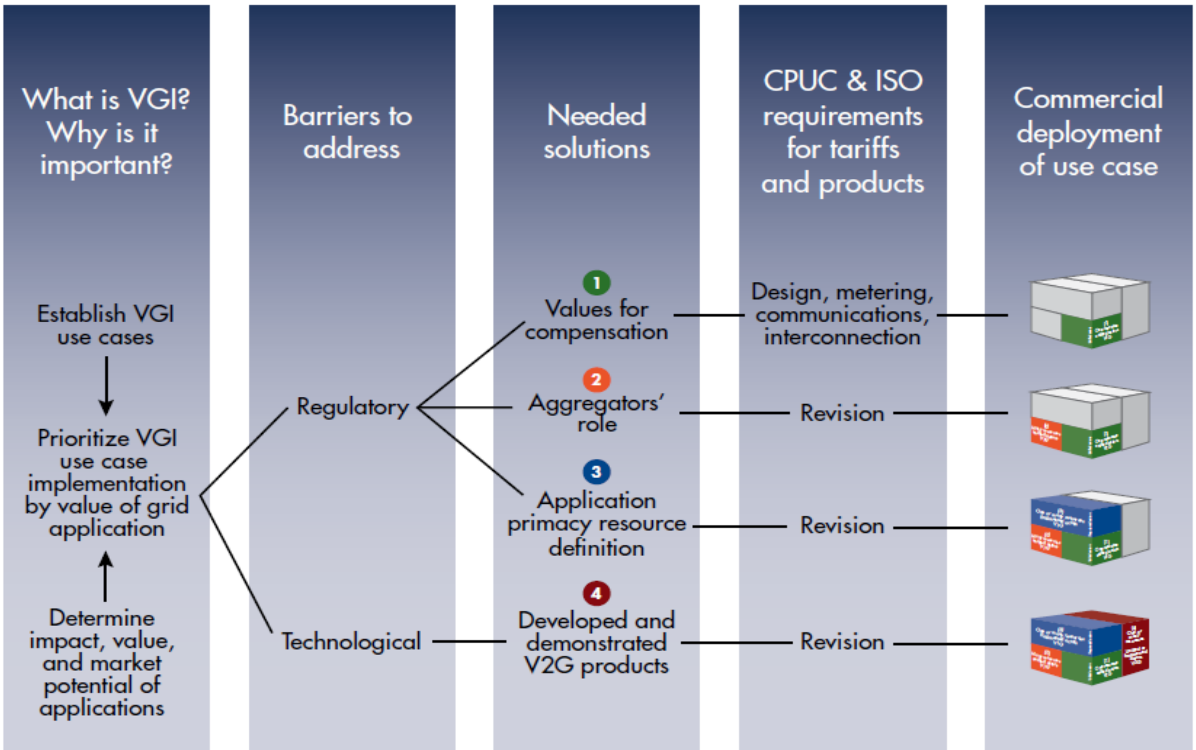
1) Identifying the resource and determining at which point grid services are measured;

2) Determining what entities may aggregate the resources and interact with the wholesale markets;

3) Determining how to capture distribution system benefits, monetize those benefits, and distribute them to the various actors; and

4) Determining the primacy among the potential VGI activities.

The framework for policy creation developed by CPUC in various scenarios are given below.



Proposed framework for developing VGI supportive regulations

Policies for various scenarios (CPUC)

Scenarios and Needed Actions for Vehicle-Grid Integration	Customer Benefits	IOU/Distribution System Benefits			Wholesale Market Benefits		
		Tariff Design	Communication	Metering	Product Design	Commu nication	Metering
One Resource Unified Actors V1G	No action needed.	• Define DR Value and develop tariff • Measure benefits for renewable-following and neighborhood scheduling through demonstration projects • Develop tariffs for DR and other distribution benefits	Select communication standard(s)	Choose to use facility meter or resource meter	Refine NGR and PDR products to account for the response time, size and flexibility of a vehicle resource	Select commu nication standar d	Define metering location and accuracy requirements
+Aggregated Resources	Determine the marginal benefits of subscribing to an aggregation program.	Develop products to support aggregated resources	Determine communication requirements for an aggregated resource	Determine metering requirements for an aggregated resource			
+Fragmented Actors	Determine the marginal benefits of a regulatory solution to the agency issue.	Design tariffs based on the resource definition	Determine communication requirements based on resource definition	Determine metering requirements based on resource definition			
+V2G (Vehicle to Grid)	Determine impacts to reliability, economics and customer mobility.	Wait to develop rules until automakers indicate when commercial technologies will be available. Determine incremental benefits, tariff, and interconnection requirements for bi-directional resources.					

Annexure IV: Technical Simulation Results

Simulation for a residential feeder

All the figures given show the changes in the voltage (graph1), current (graph 2), apparent power (graph 3), true power (graph 4) and reactive power (graph 5). The focus is primarily focused on graphs 1 and 2 (voltage and current). This simulation is done to establish a baseline scenario.

As discussed, impedance model is considered as a short high voltage 3 phase system, for which there would be considerable resistances and inductances, due to inherent properties. The resistance and inductance of the grid oppose the flow of electricity in the system. On increasing the impedance of the model, the variations in the transformers is assessed.

The impedance in the model is given by

$$Z = R + jX$$

Where

Z: Line Impedance

R: Resistance of the line

X: Per phase Inductance of the line

Standard values for different voltage systems

Type	R (Ω/km)	X(Ω/km)
Low Voltage	0.642	0.083
Medium Voltage	0.161	0.190
High Voltage	0.06	0.191

The values were obtained from a research paper that focuses on grid control in low voltage grids. (Alfred Engler, 2006). The inductance of the line can be obtained by correlating the frequency and the per phase inductance as shown below:

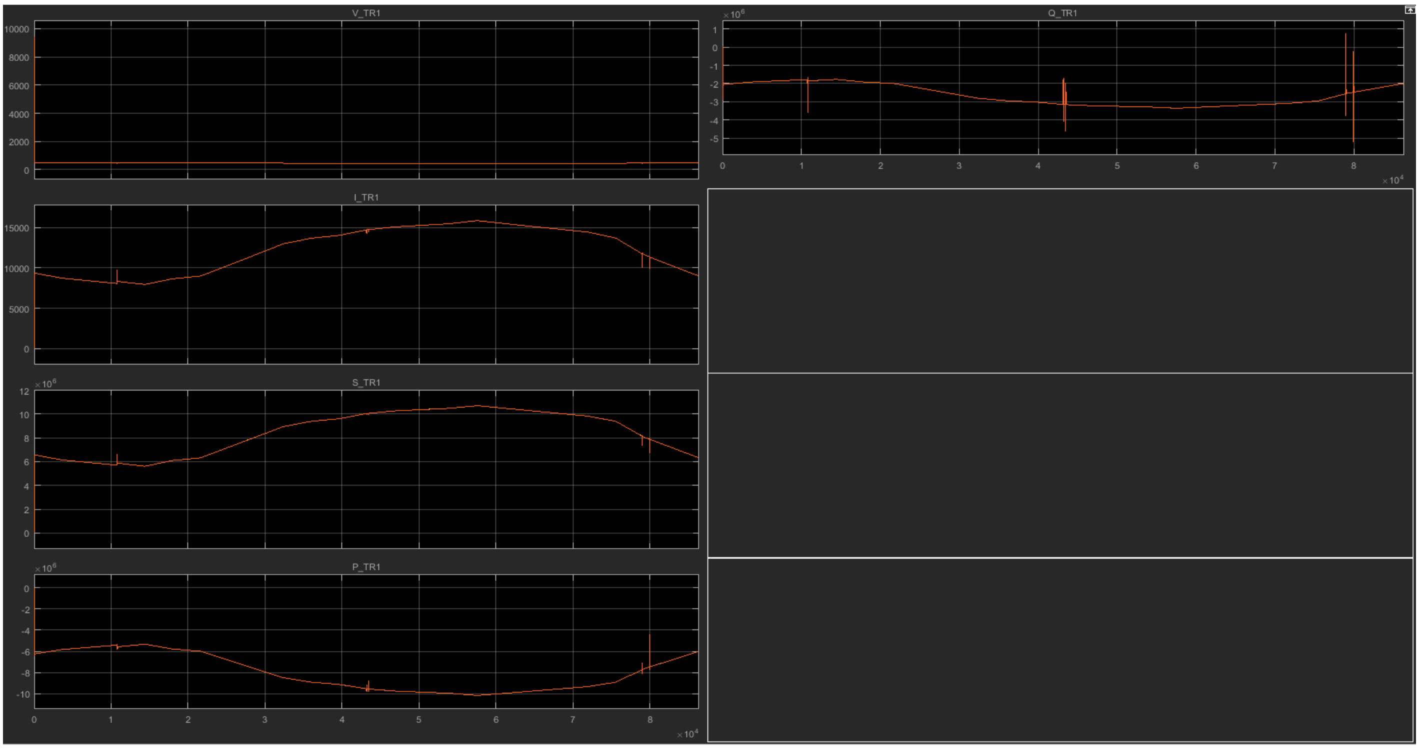
$$L = \left(\frac{X}{\boldsymbol{\omega}}\right)$$

Where,

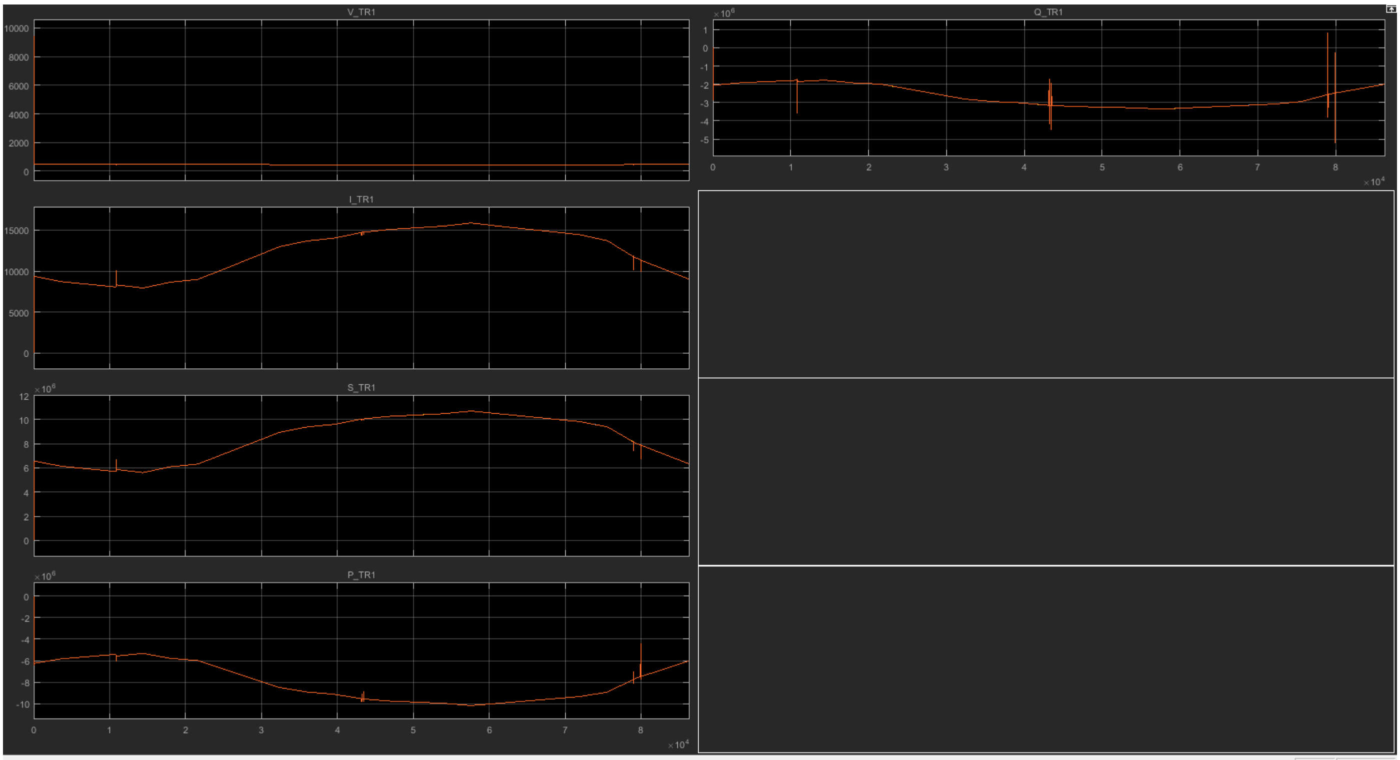
L: Inductance

ω: Angular frequency (~ 2*π*f)

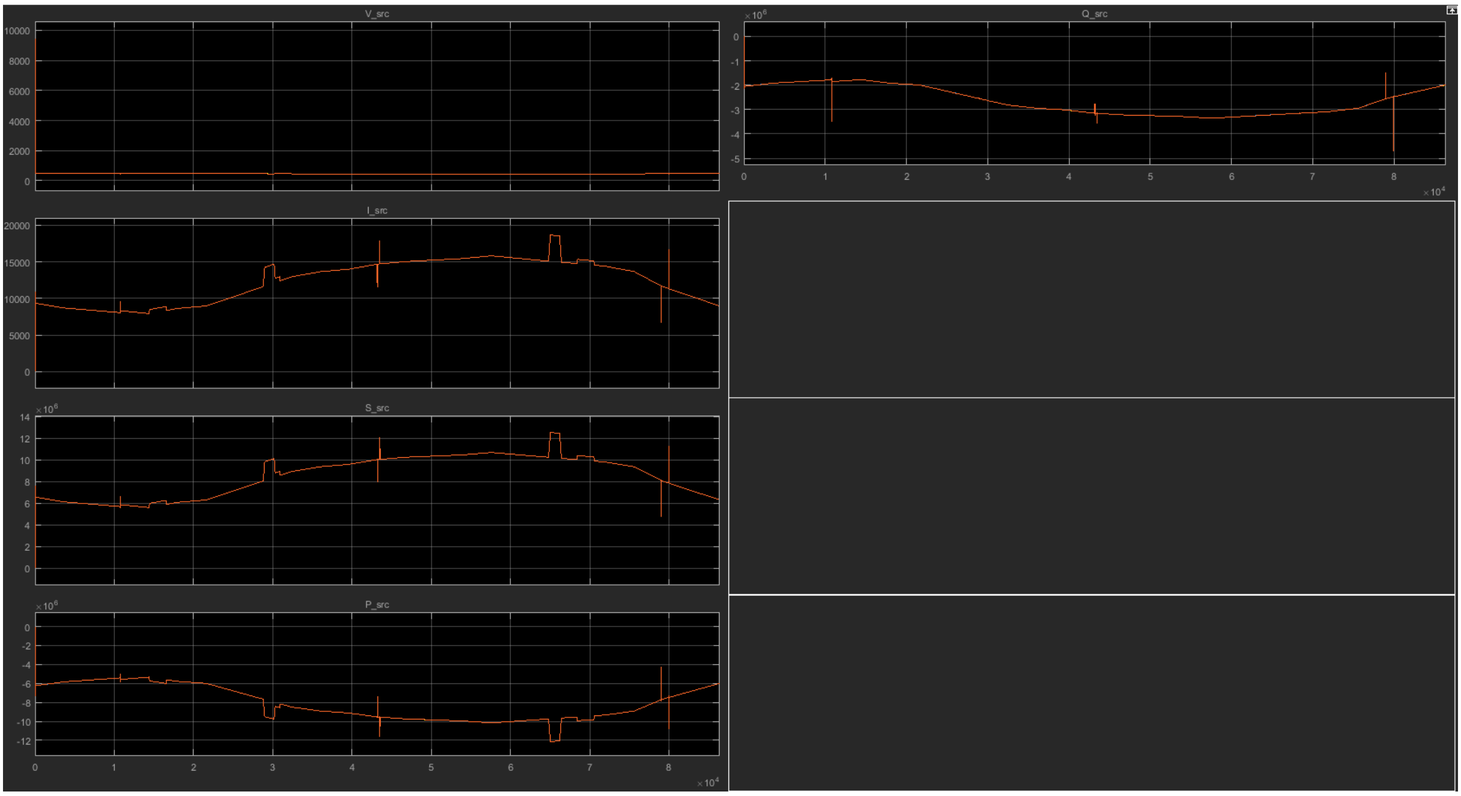
f: system frequency (60 Hz)



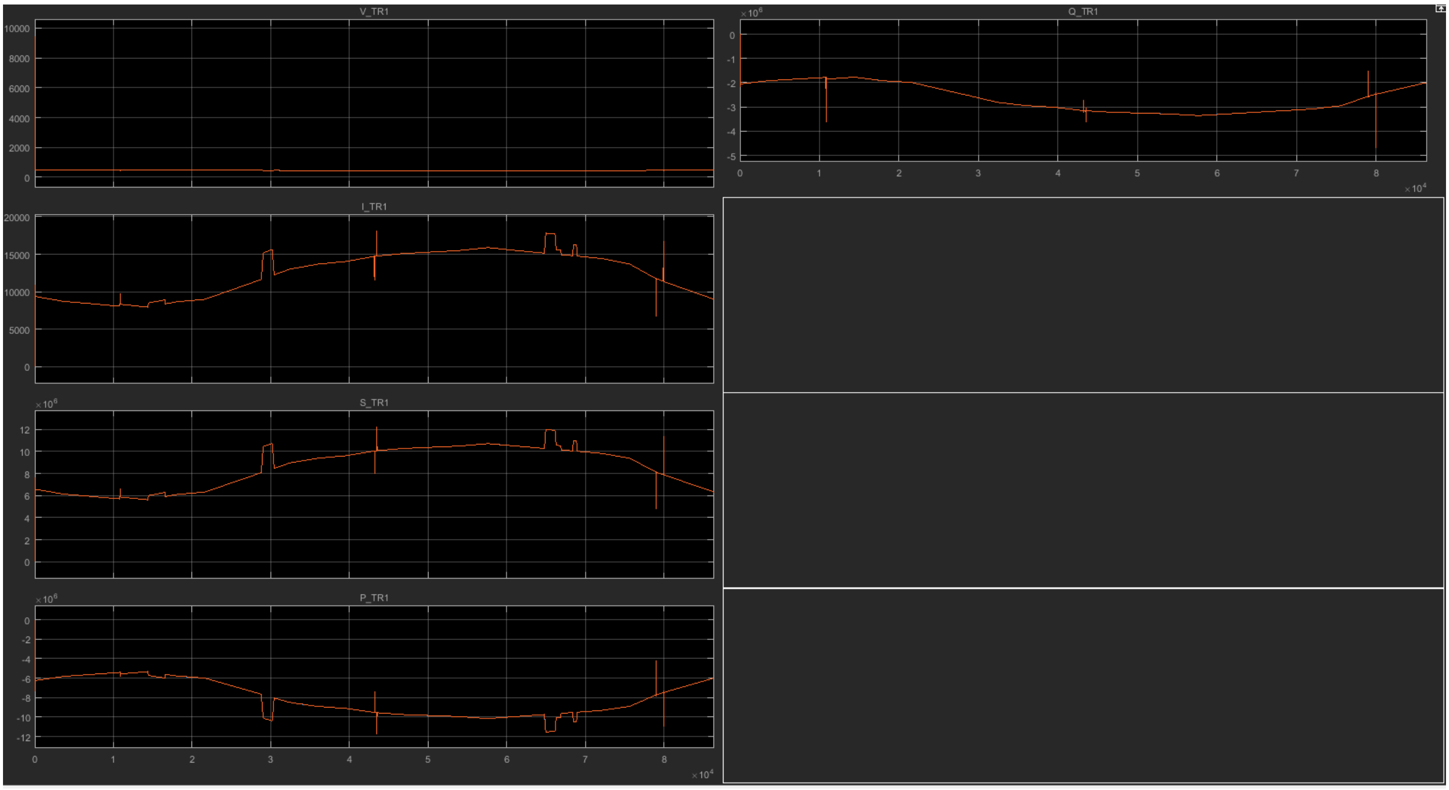
Baseline Residential Profile



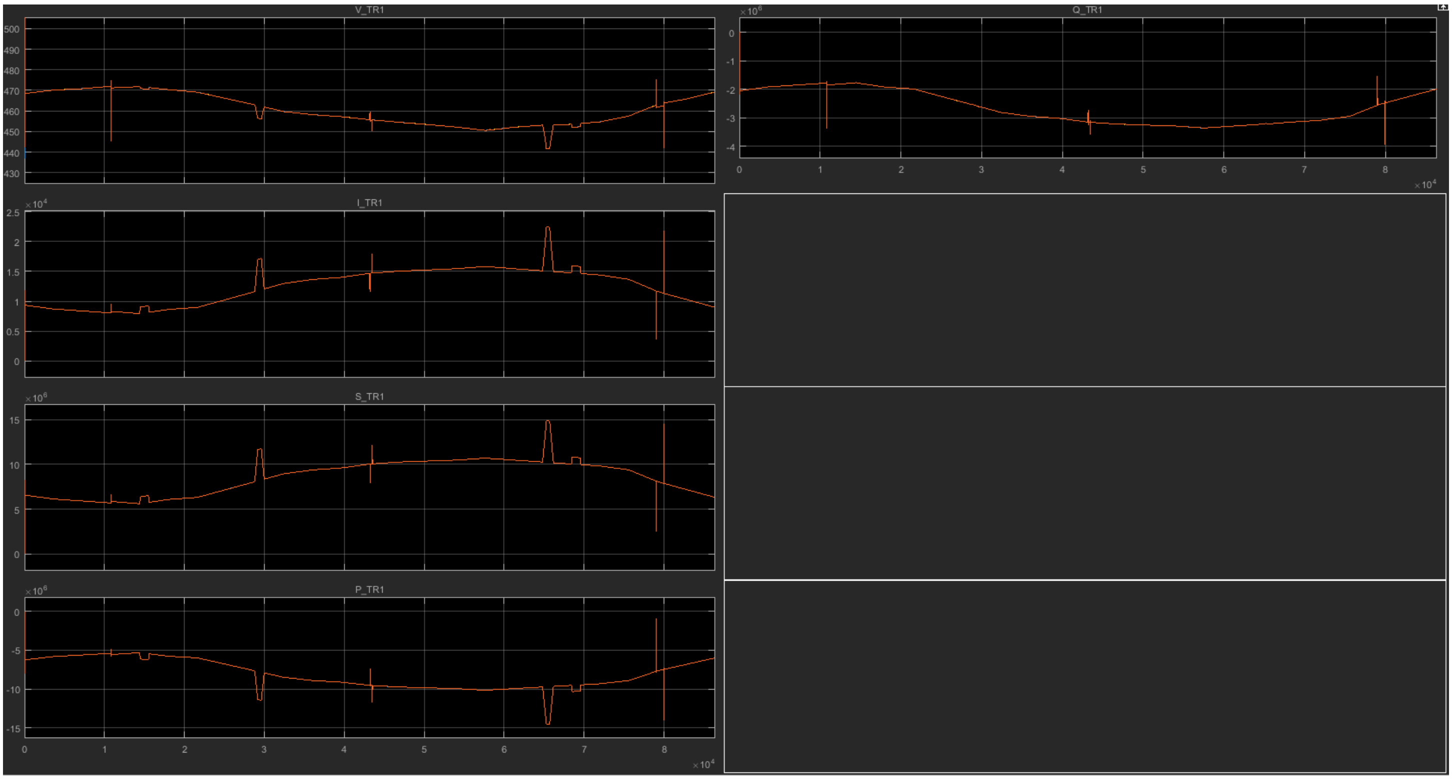
Residential Load with Impedance



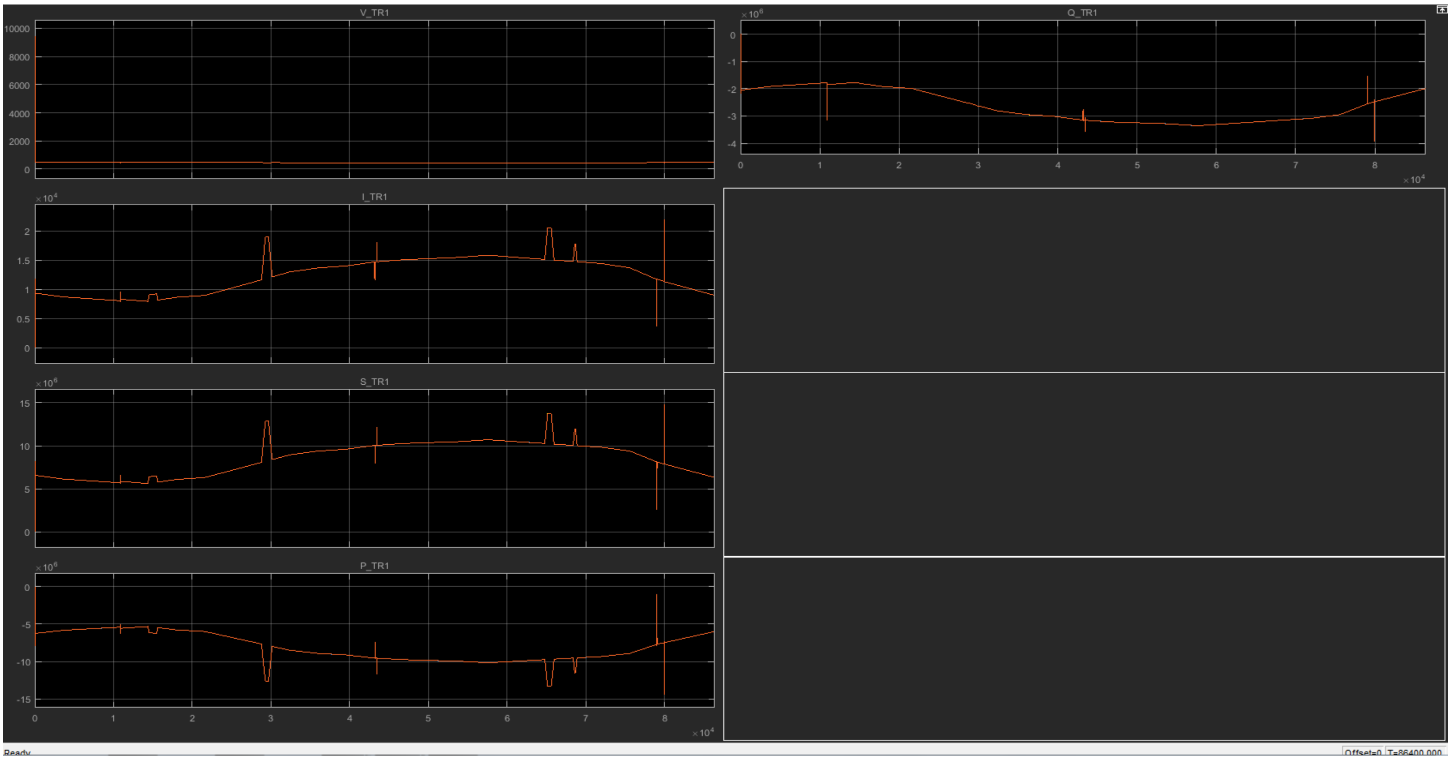
Results for a residential transformer with EV load



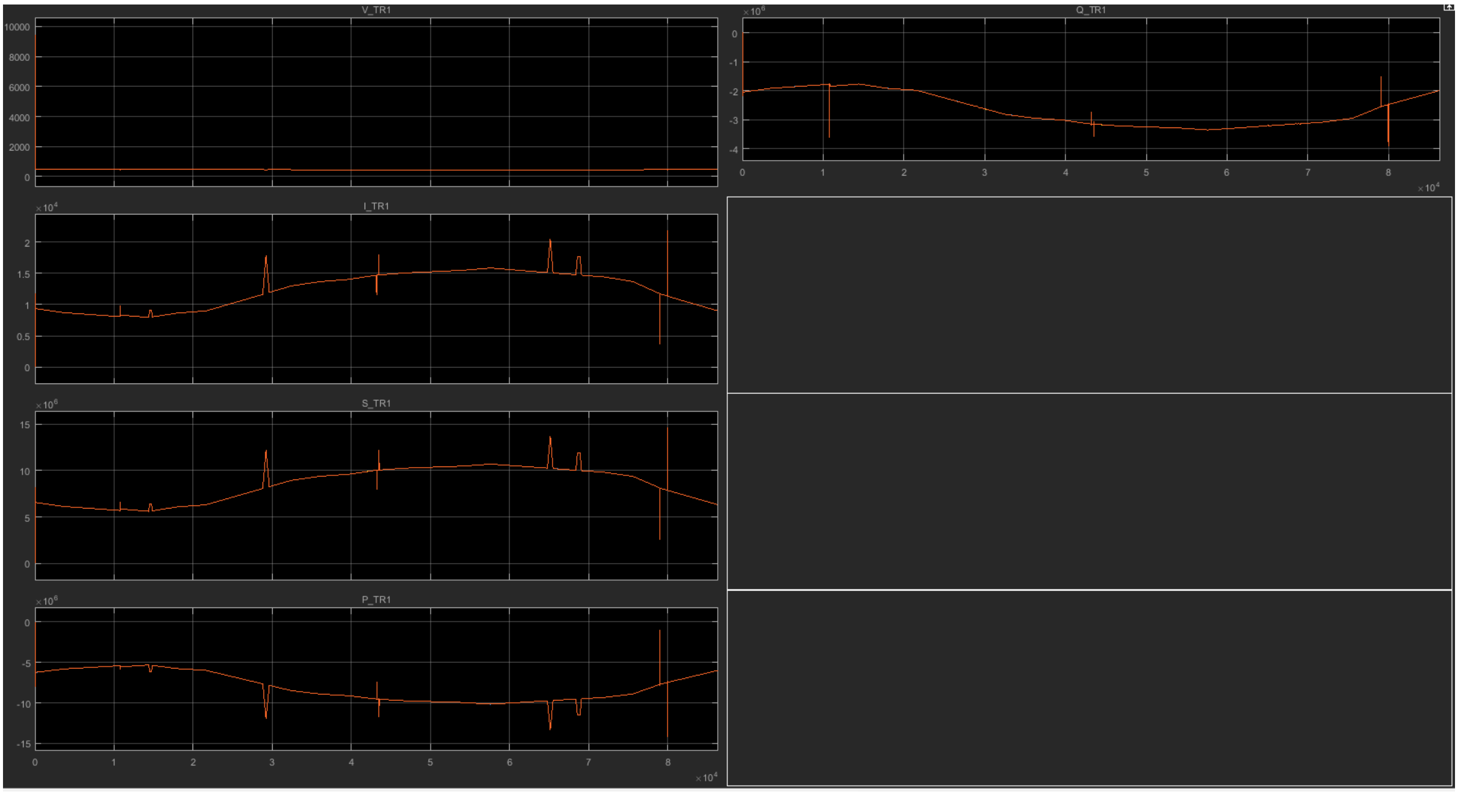
Transformer with residential and EV load with impedance



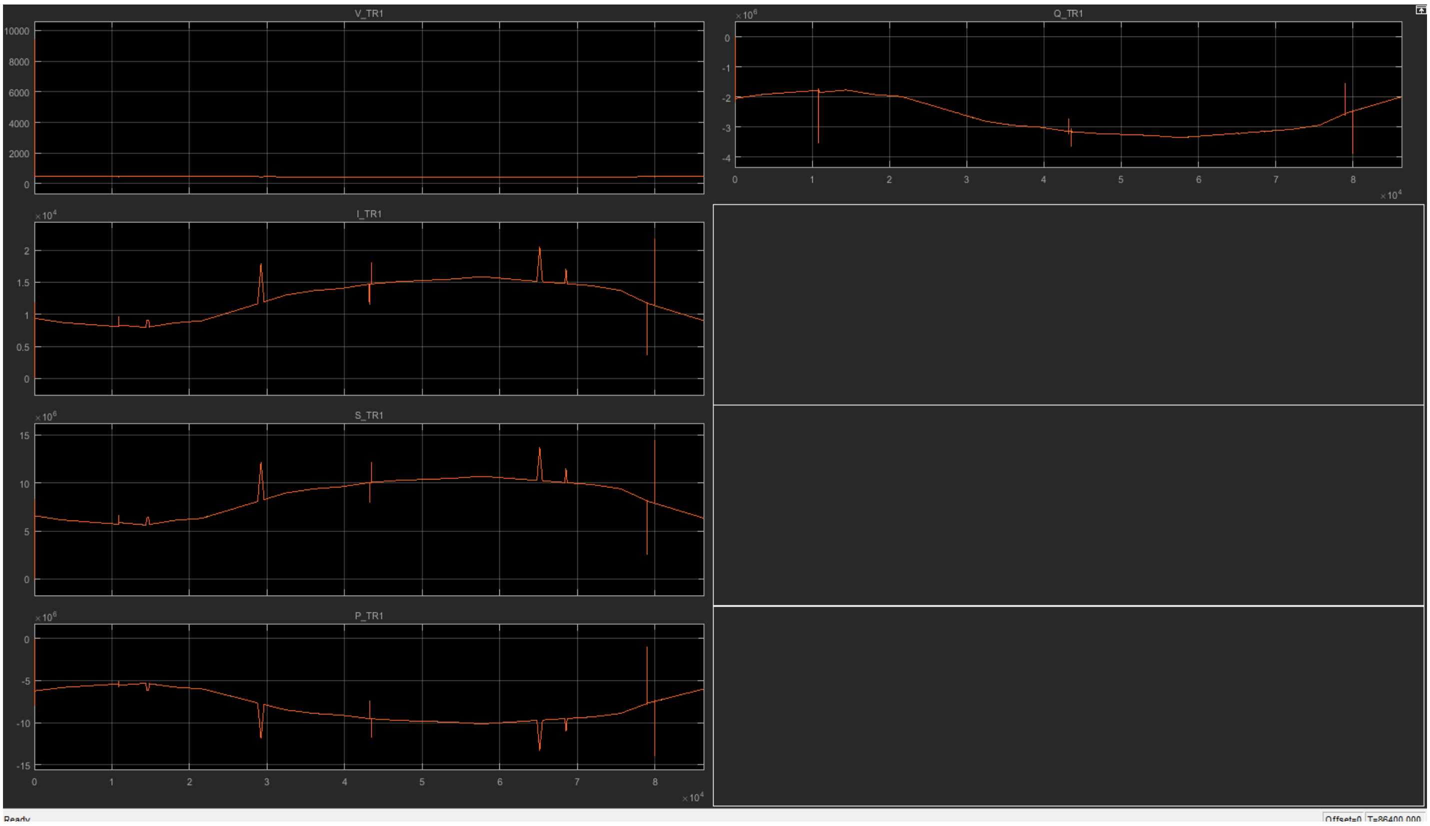
Results for Scenario 1, Case 1



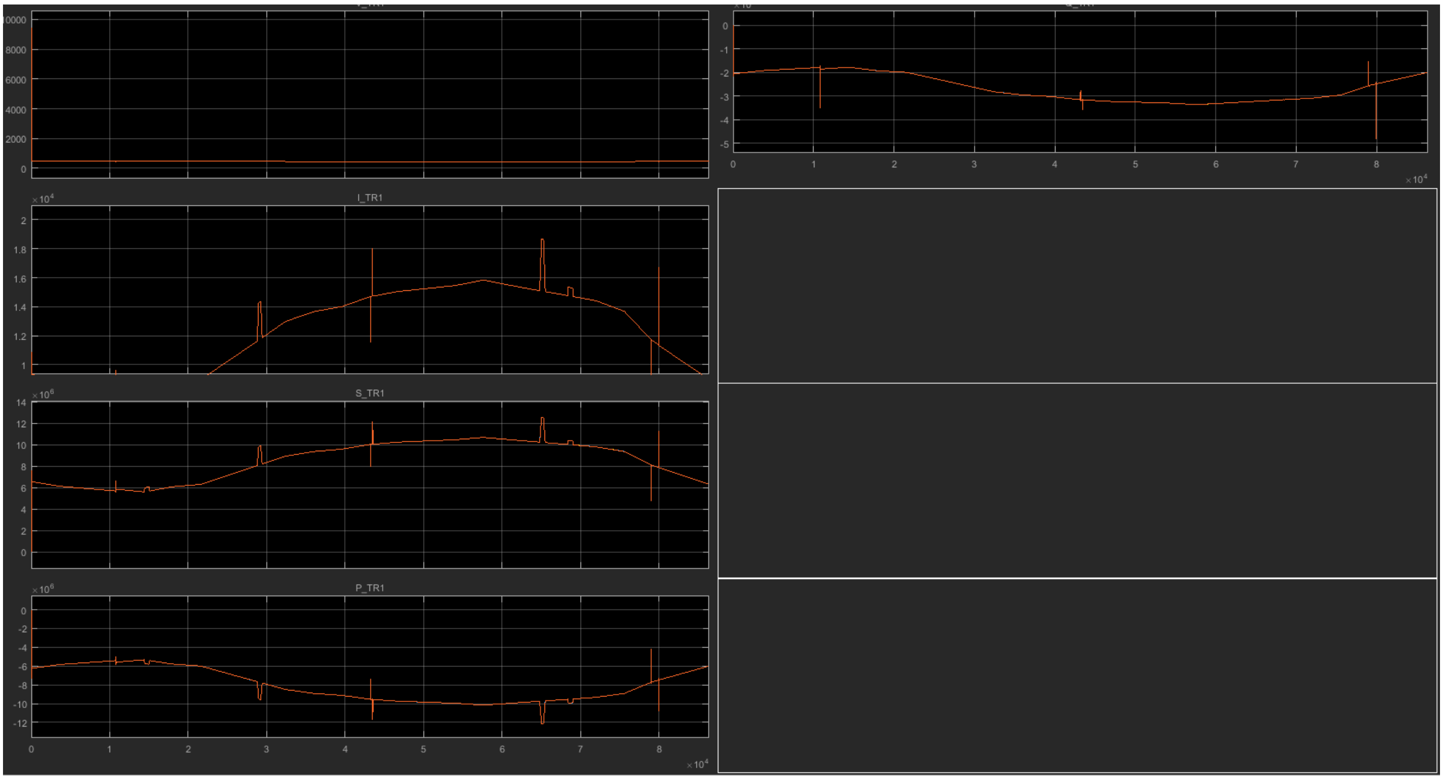
Results for Scenario 1, Case 2



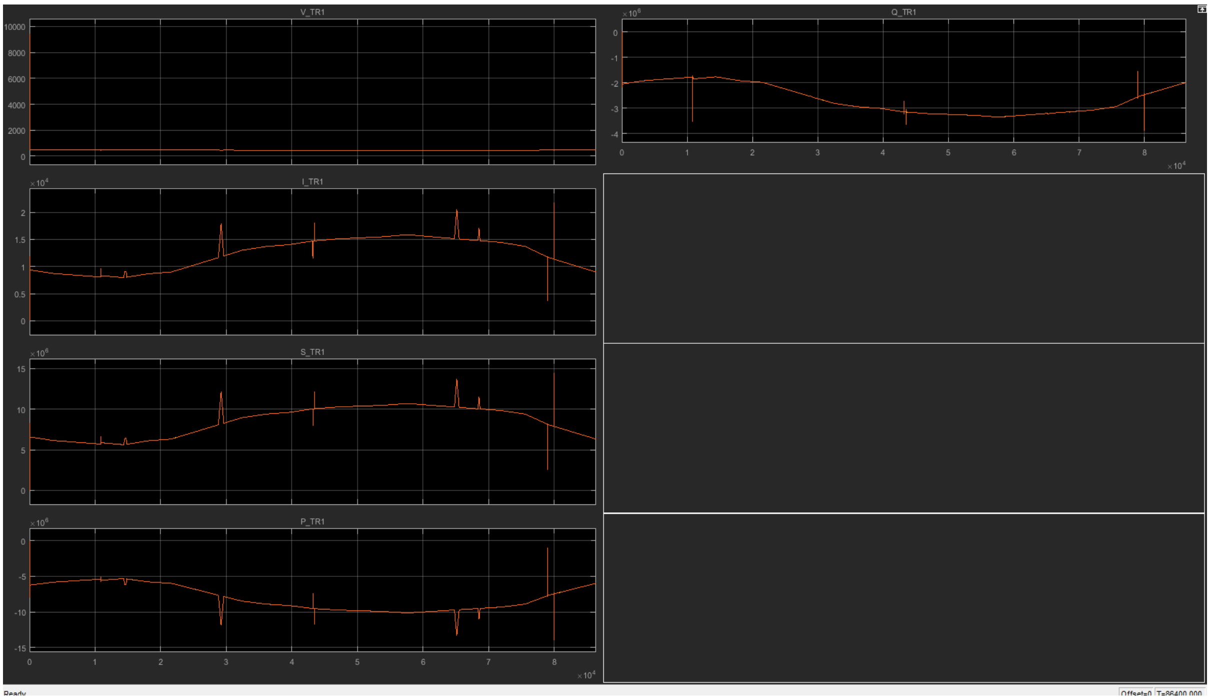
Results of Scenario 2, Case 1



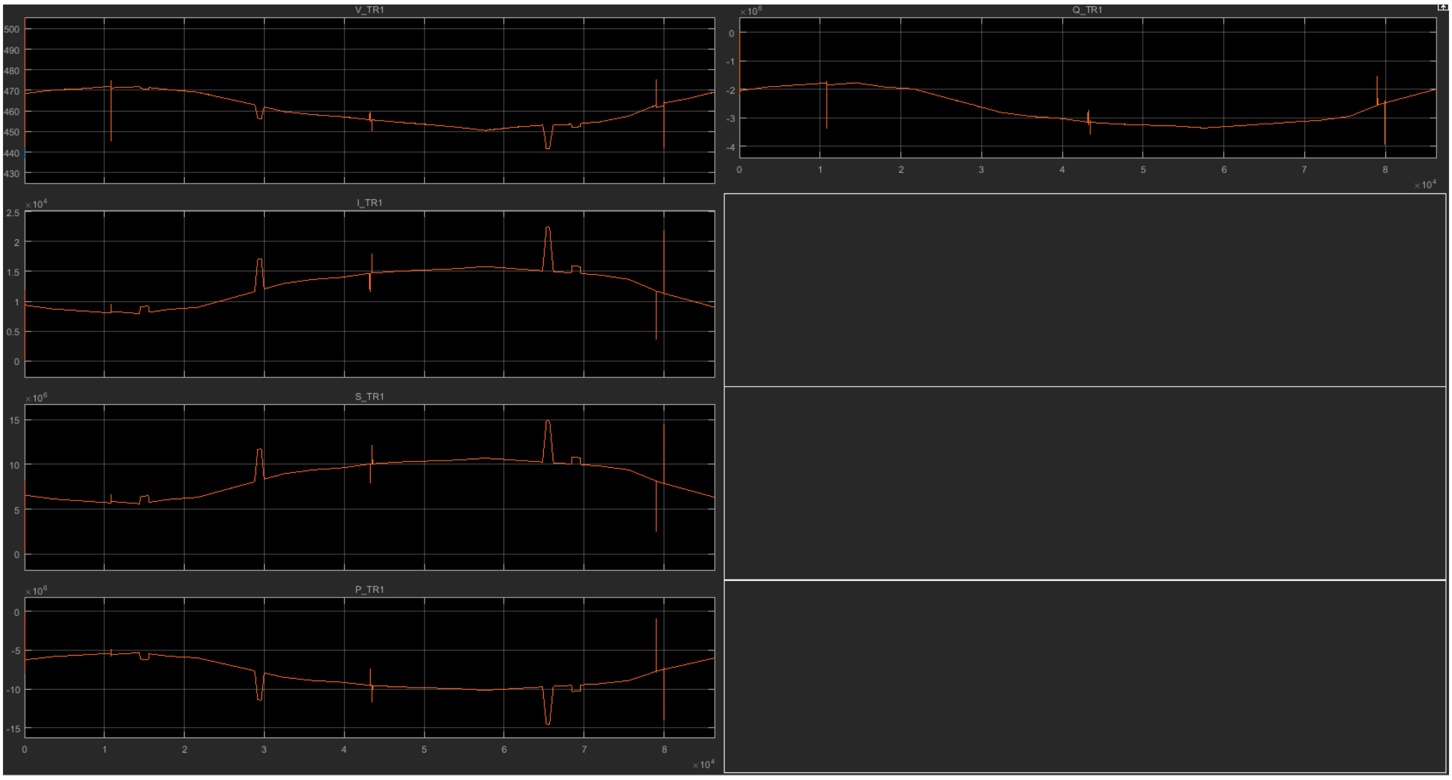
Results for Scenario 2, Case 2



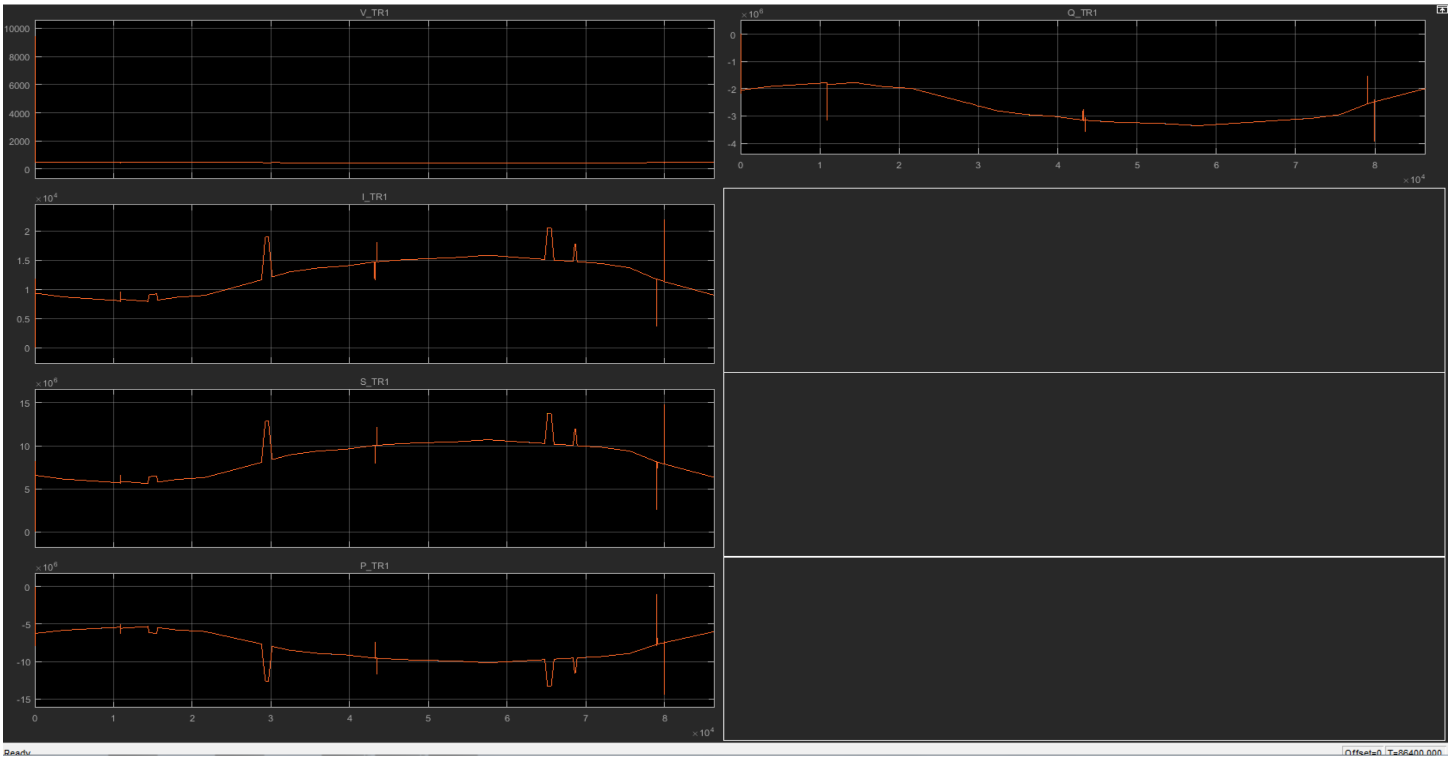
Results for Scenario 3, Case 1



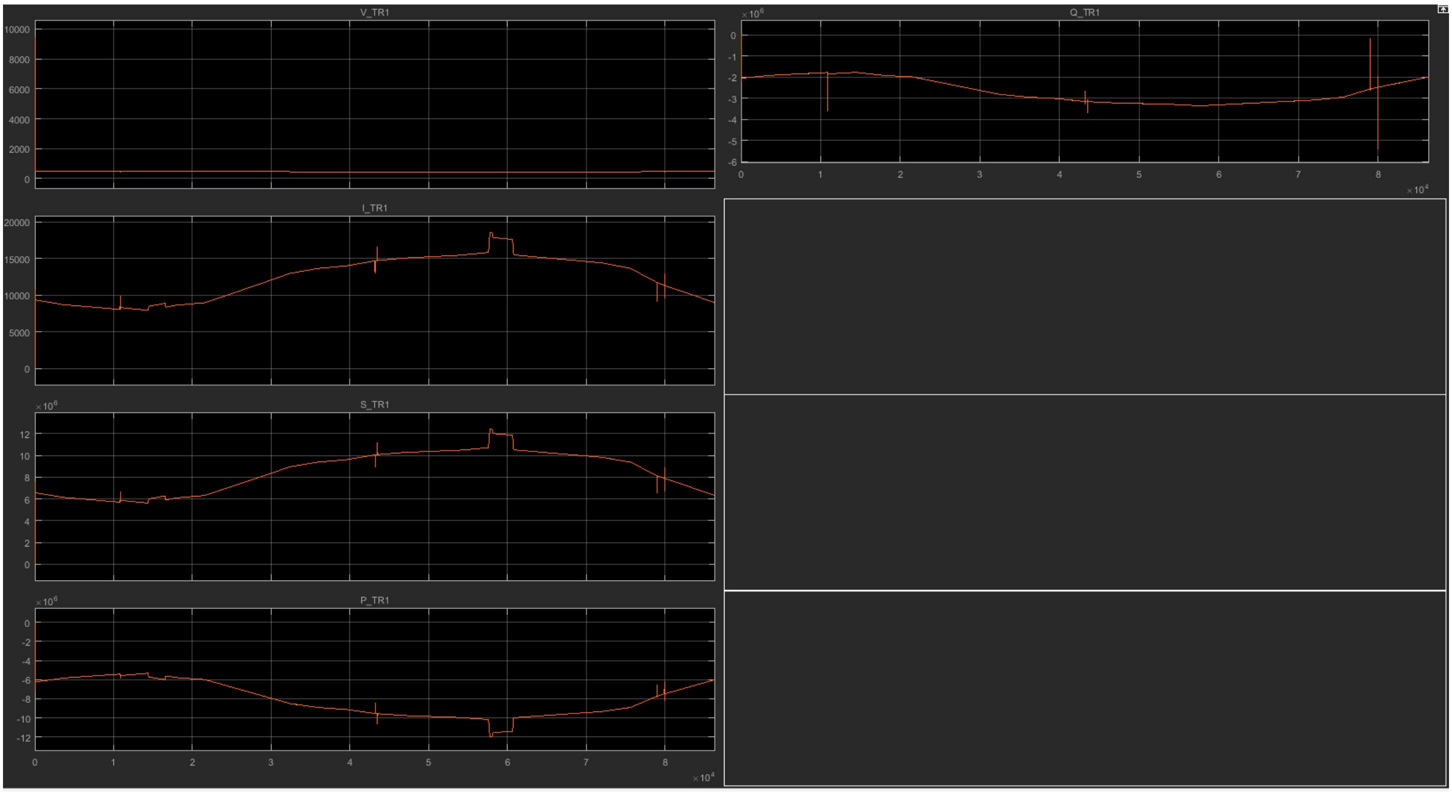
Results for Scenario 3, Case 2



Results for Scenario 4, Case 1

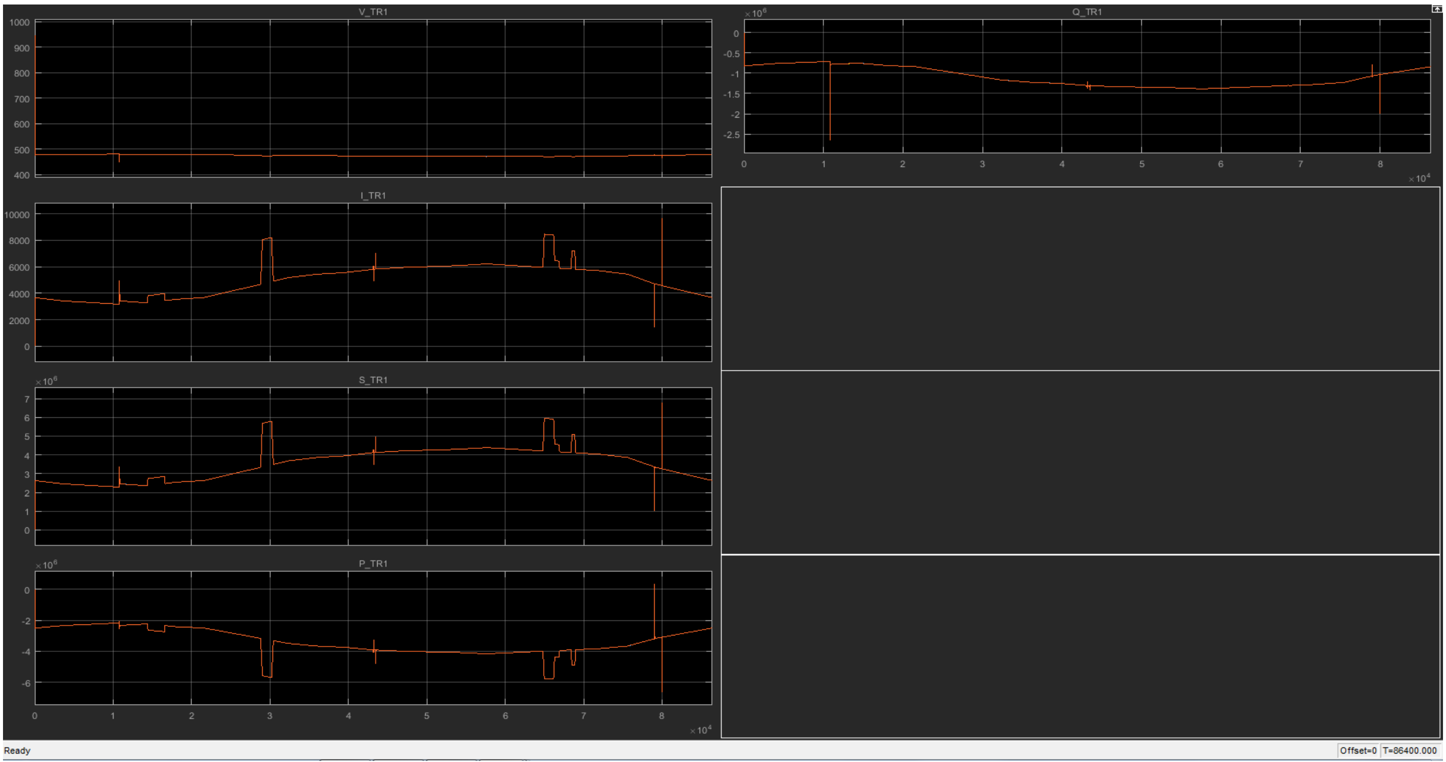


Results for Scenario 4, Case 2

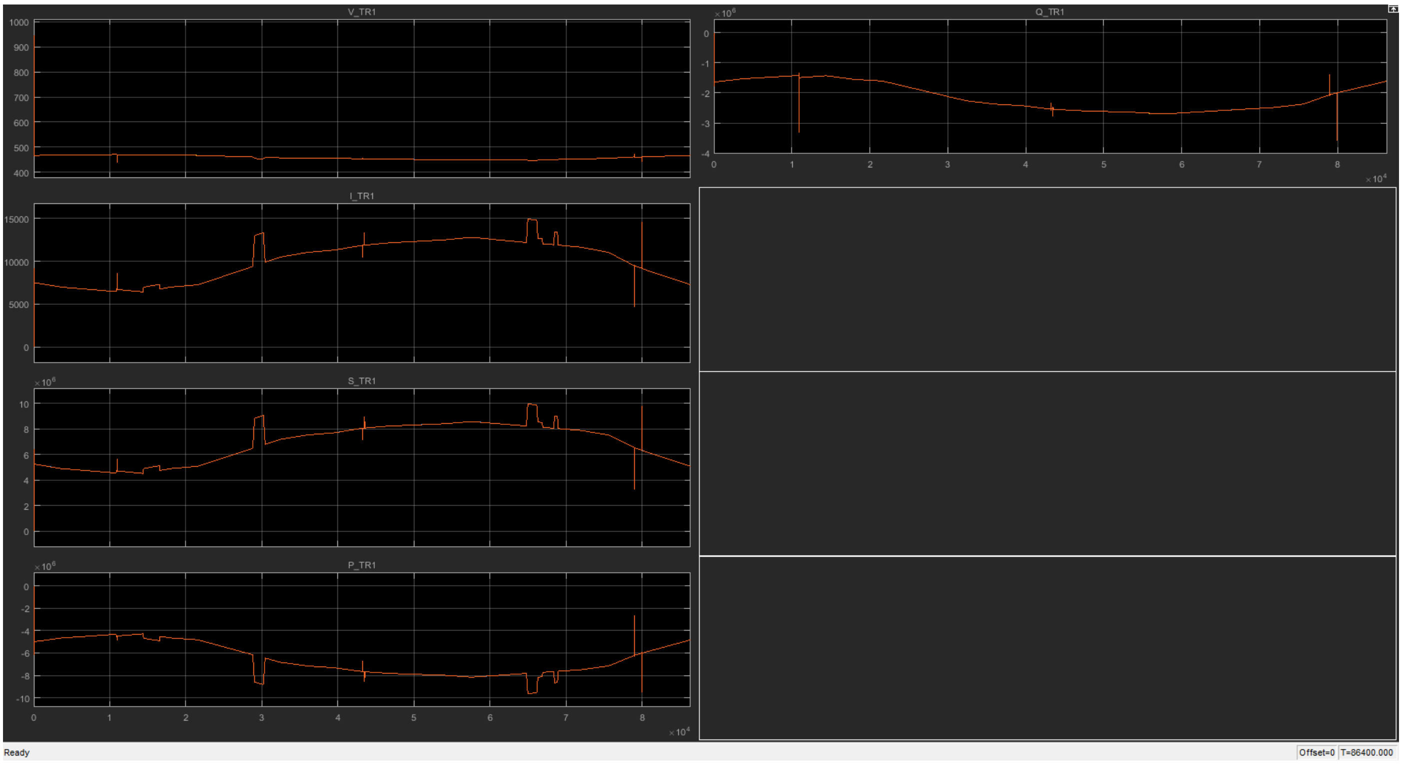


Results for Scenario 5, Case 2

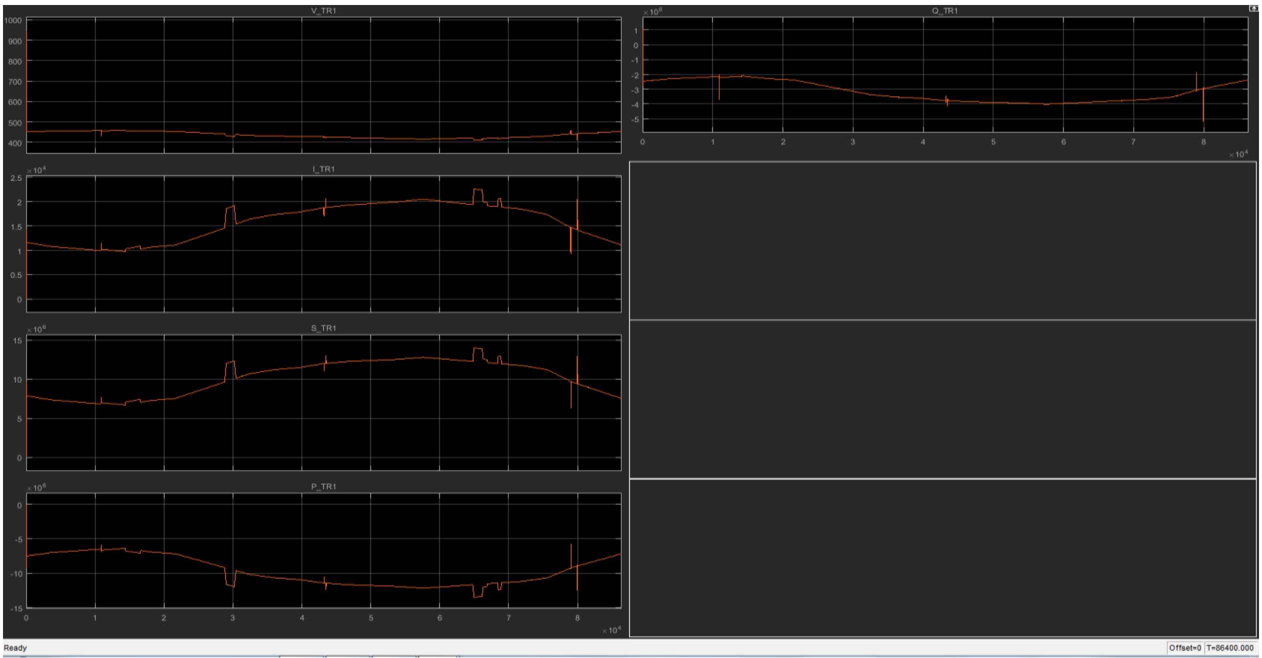
Results for Case 3



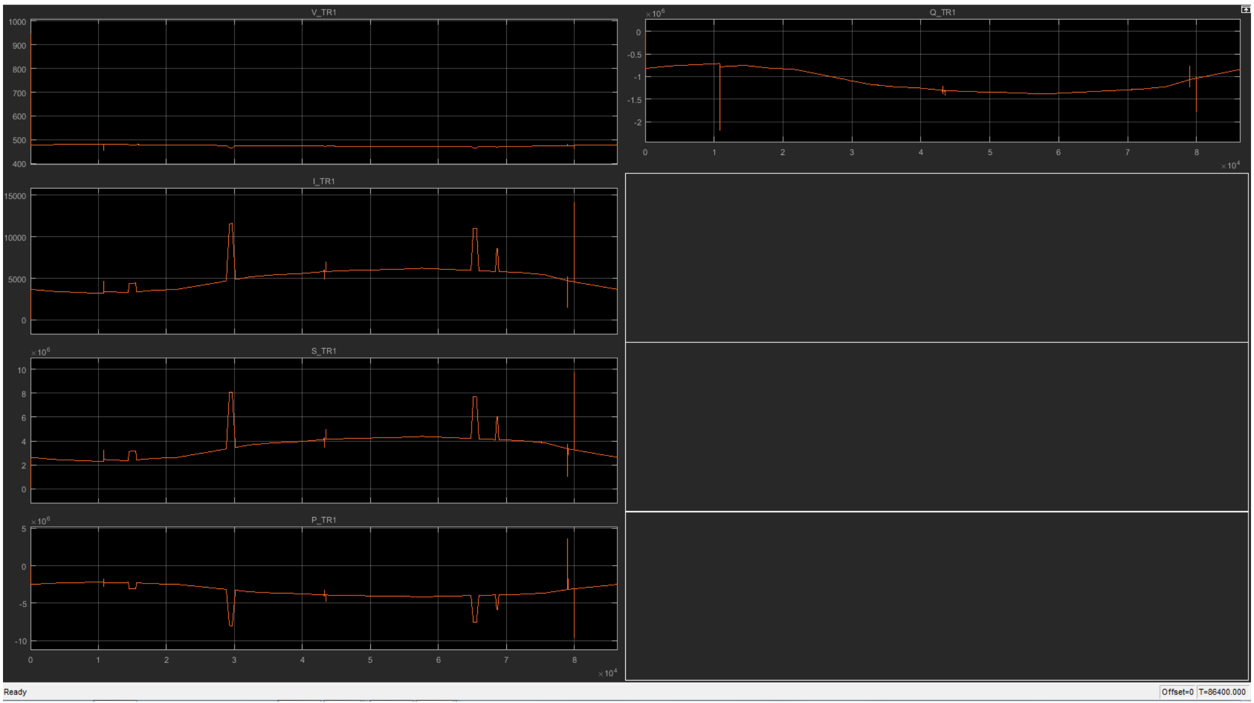
Results for 4 MW of Electric Vehicles with 4 MW of residential load



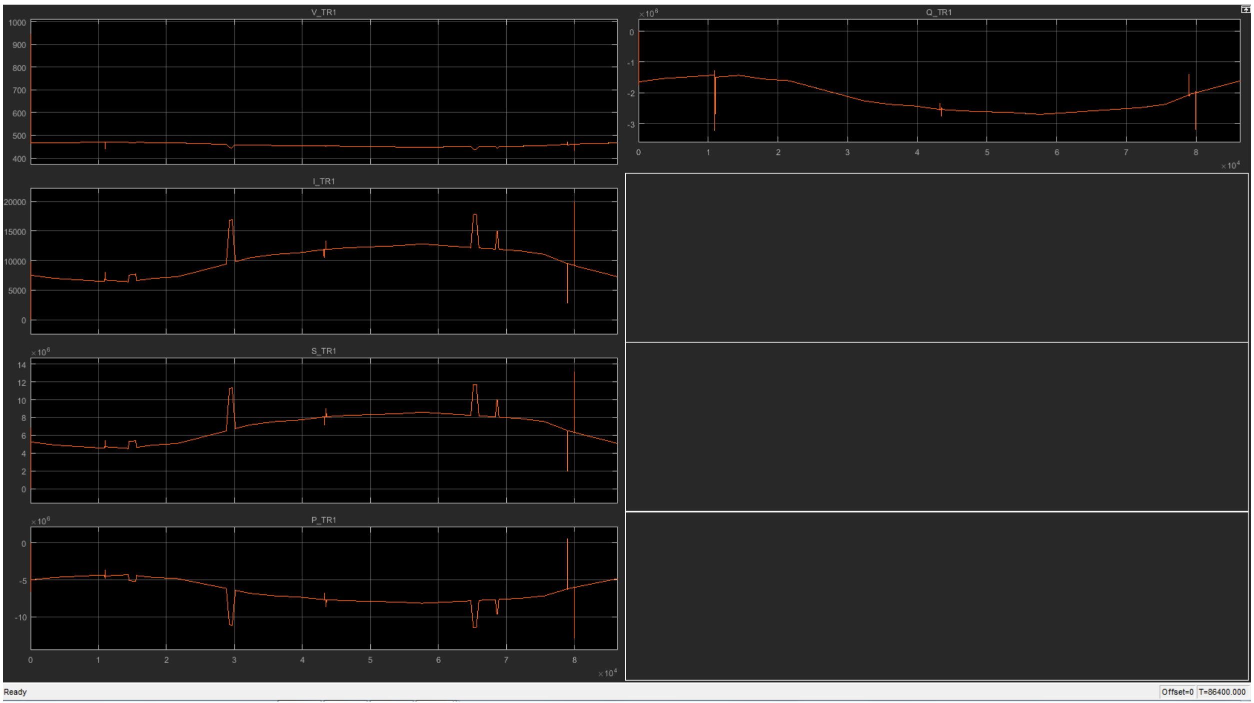
Results for 4 MW of Electric Vehicles with 8 MW of residential load



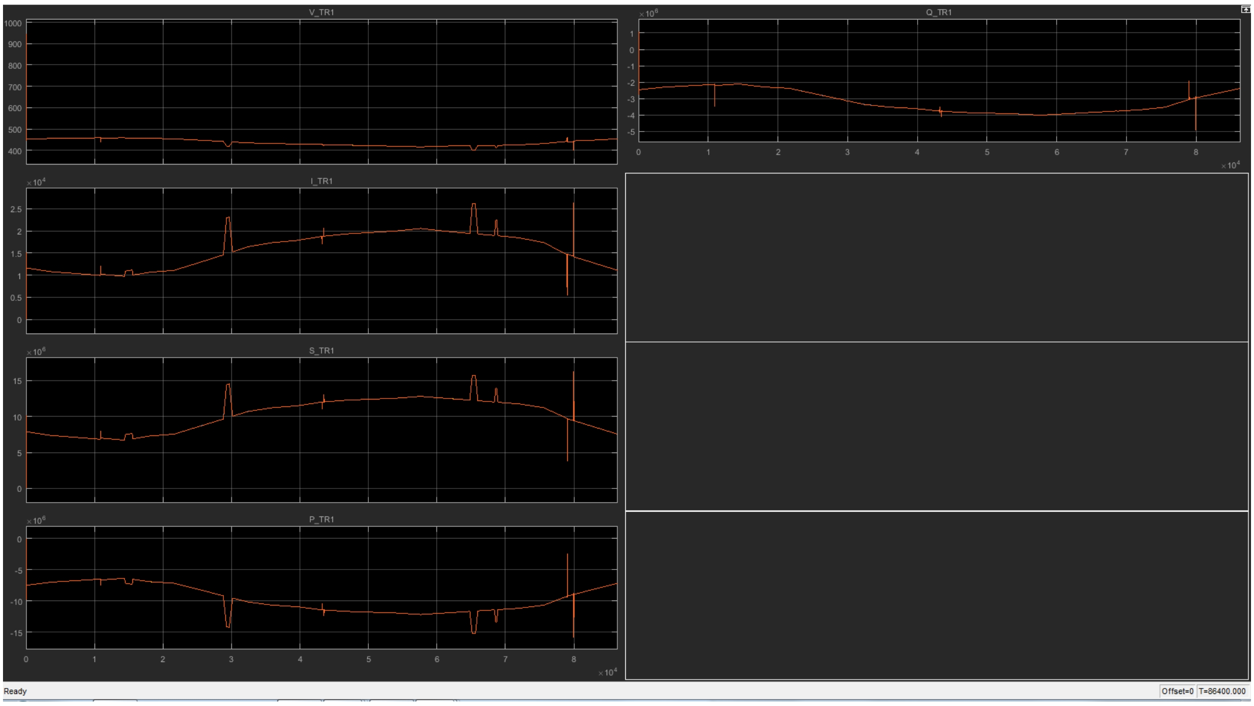
Results for 4 MW of Electric Vehicles with 12 MW of residential load



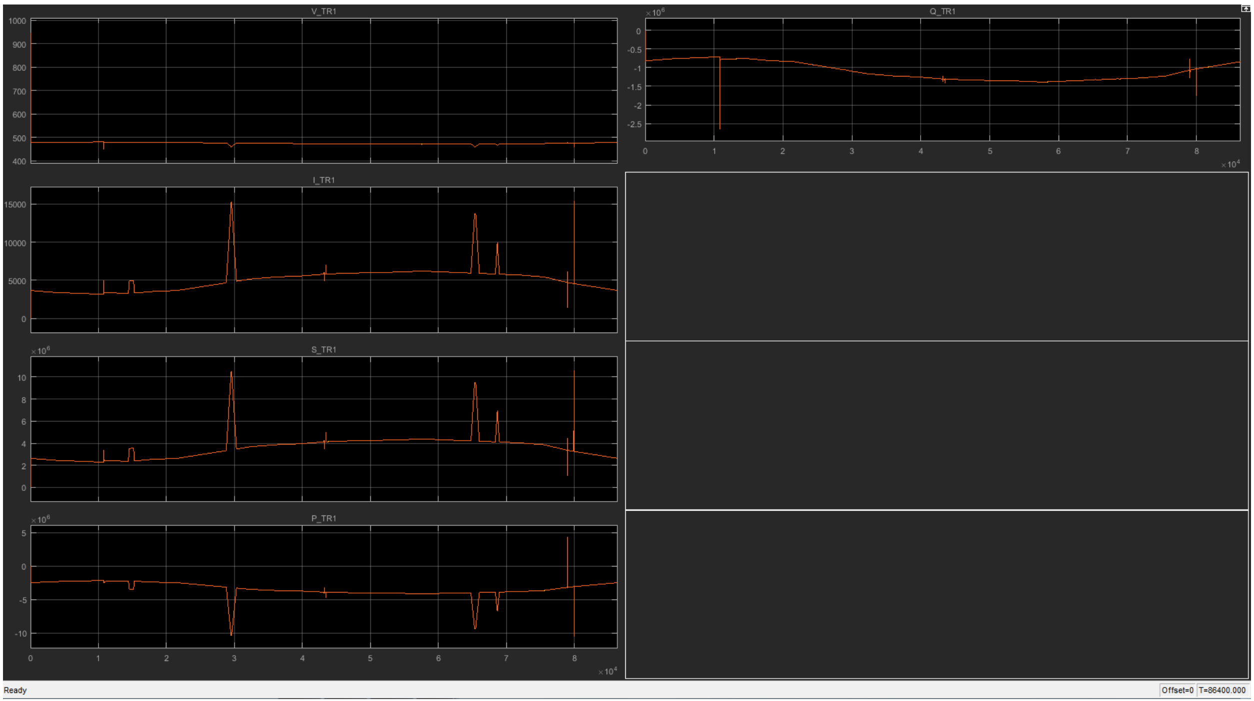
Results for 8 MW of Electric Vehicles with 4 MW of residential load



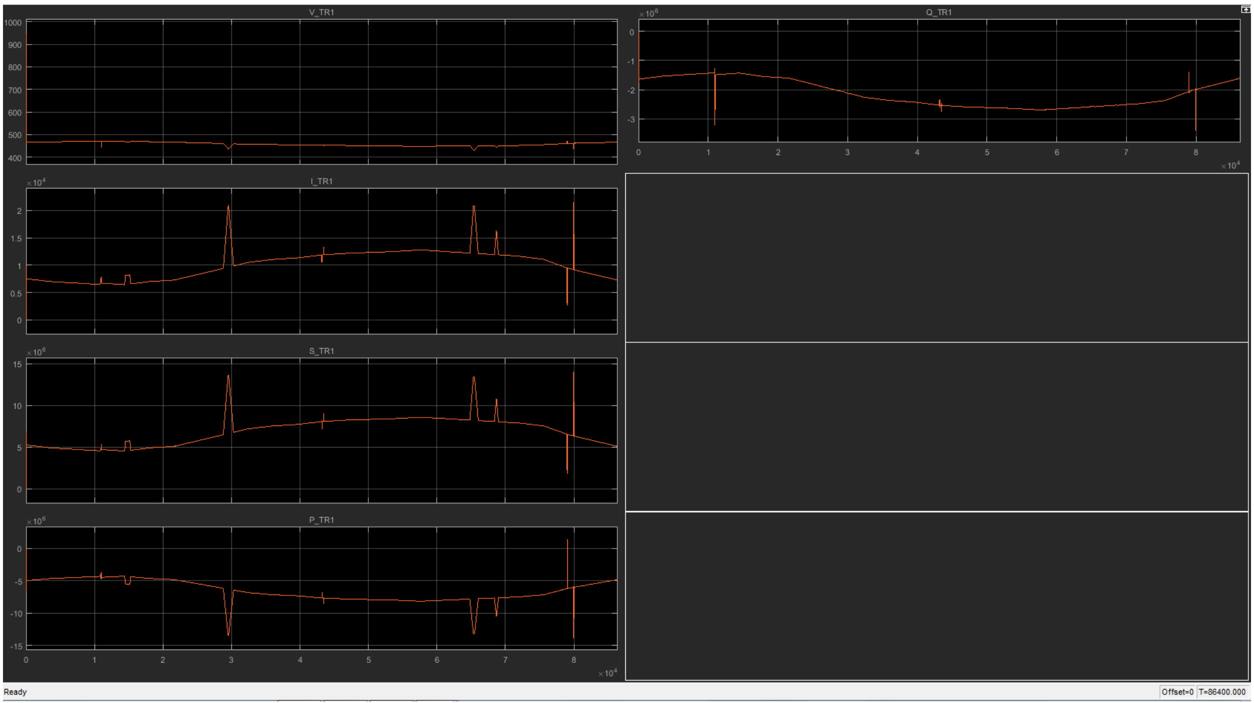
Results for 8 MW of Electric Vehicles with 8 MW of residential load



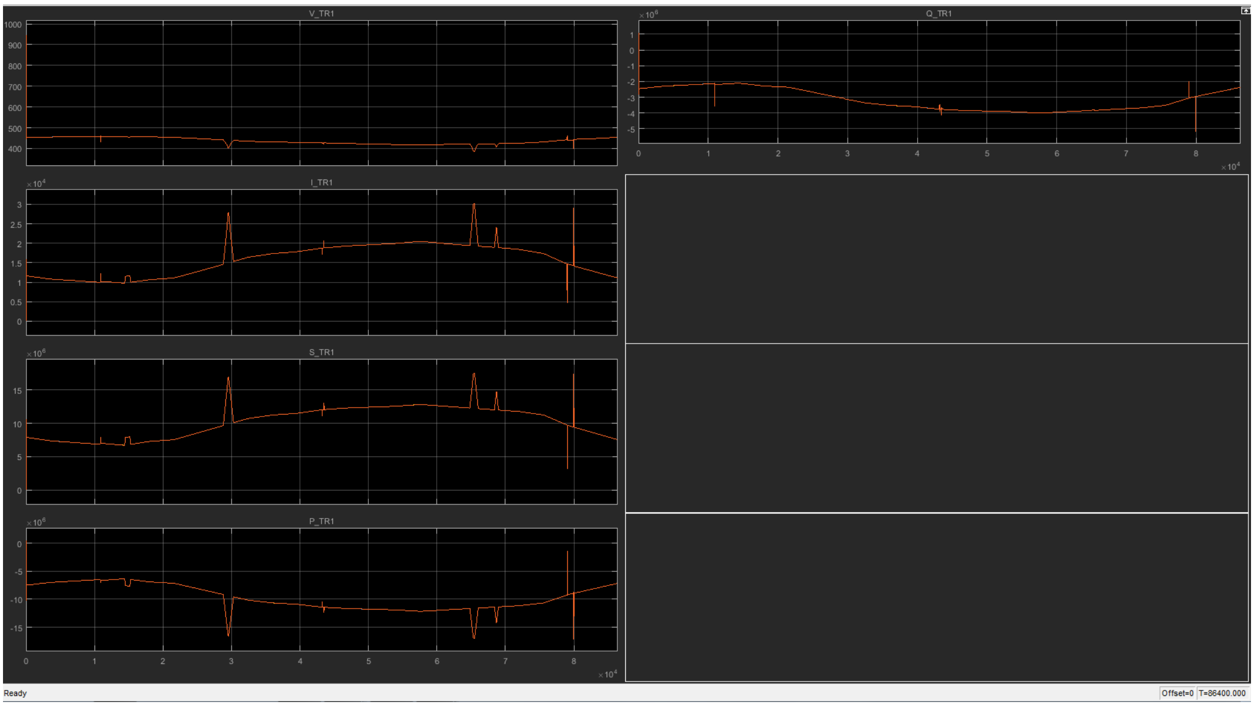
Results for 8 MW of Electric Vehicles with 12 MW of residential load



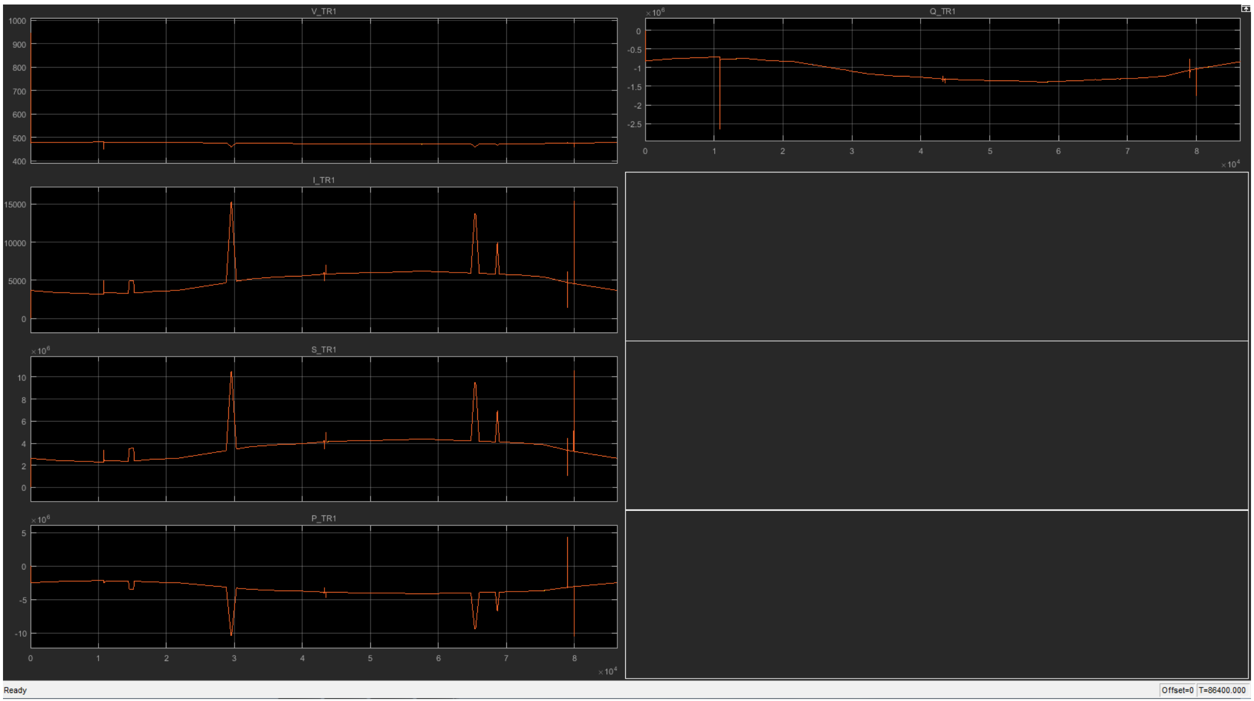
Results for 12 MW of Electric Vehicles with 4 MW of residential load



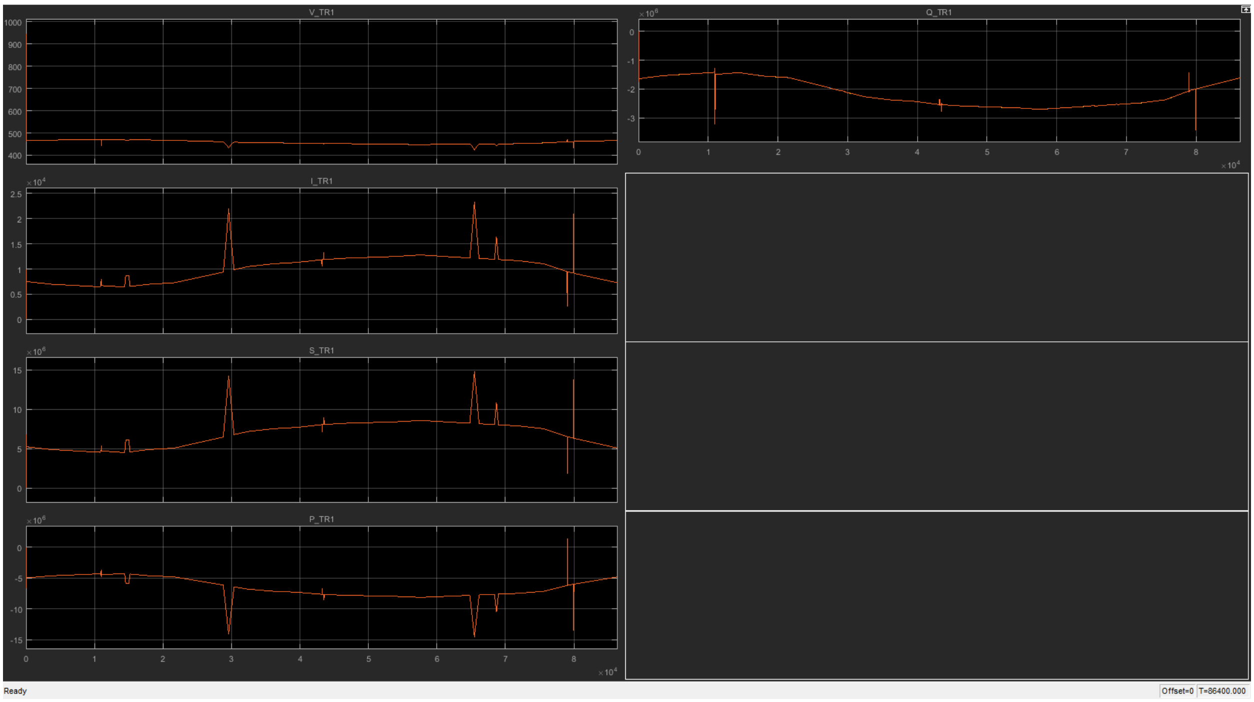
Results for 12 MW of Electric Vehicles with 8 MW of residential load



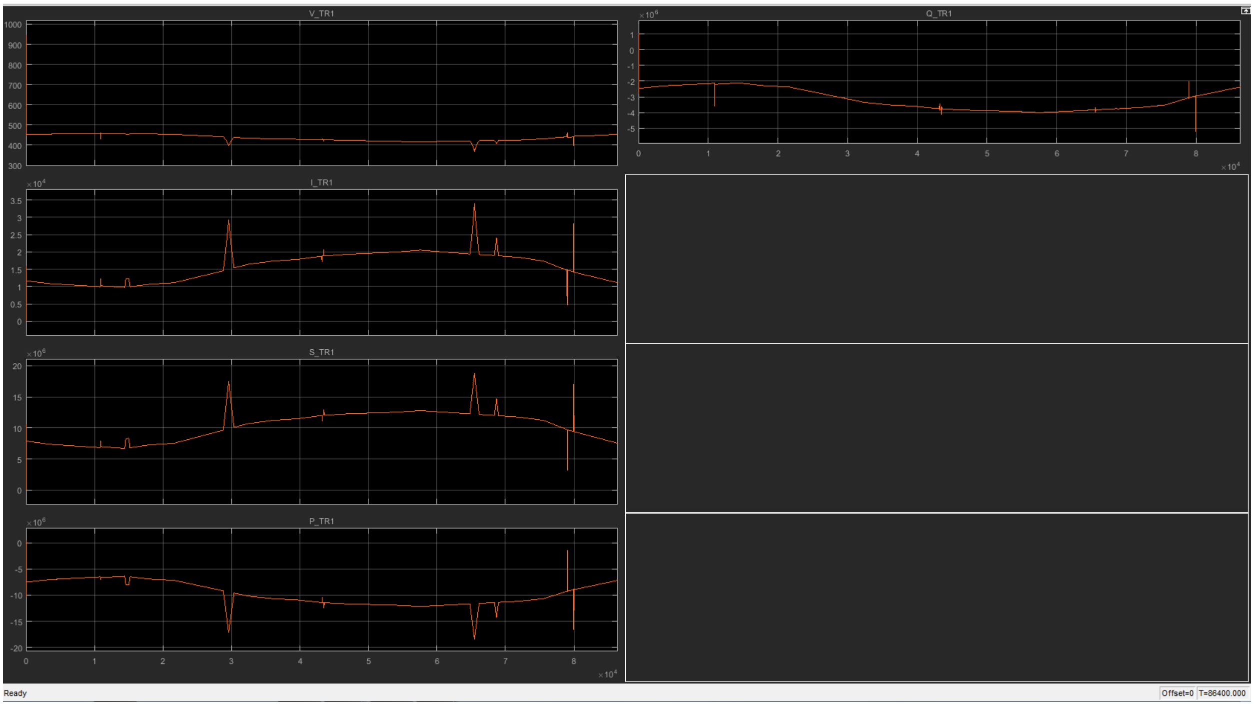
Results for 12 MW of Electric Vehicles with 12 MW of residential load



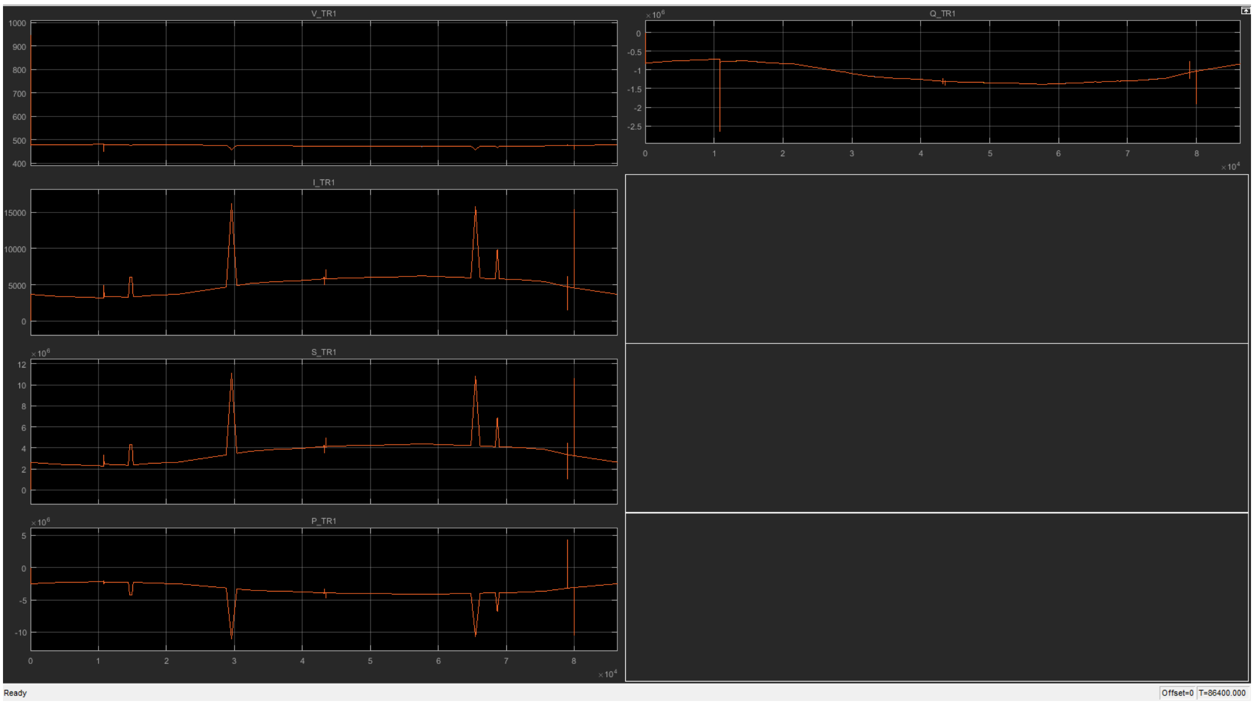
Results for 16 MW of Electric Vehicles with 4 MW of residential load



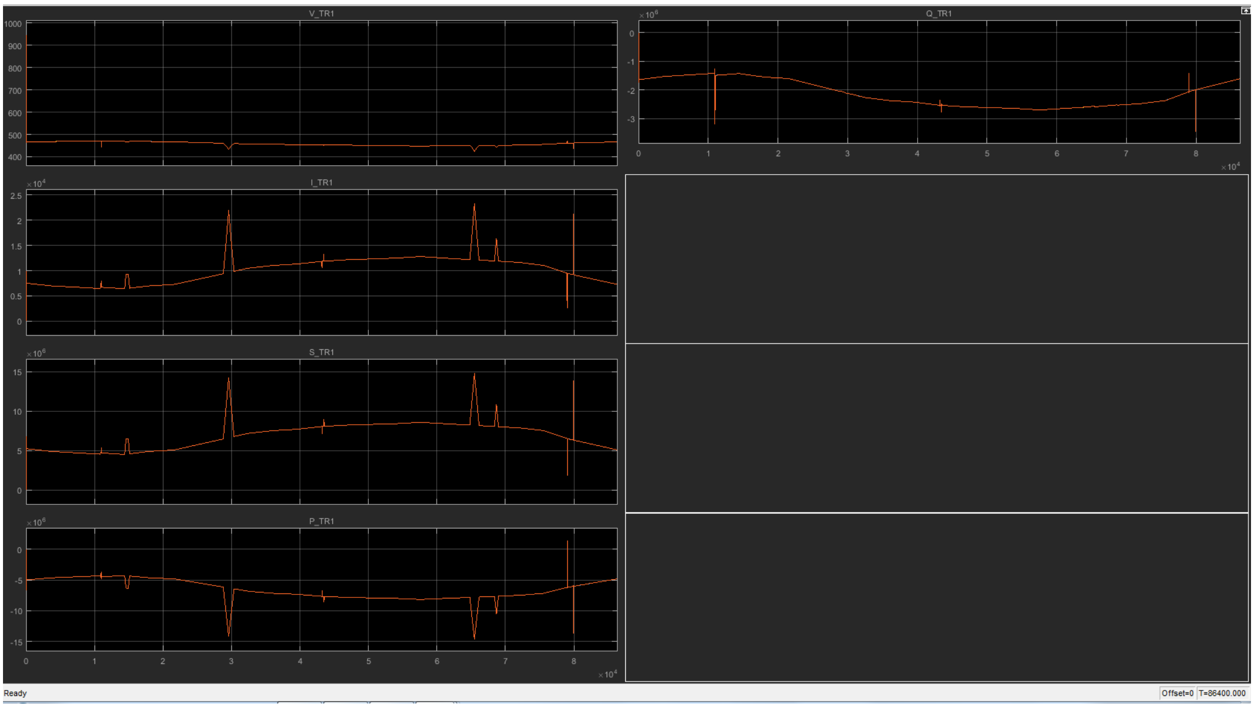
Results for 16 MW of Electric Vehicles with 8 MW of residential load



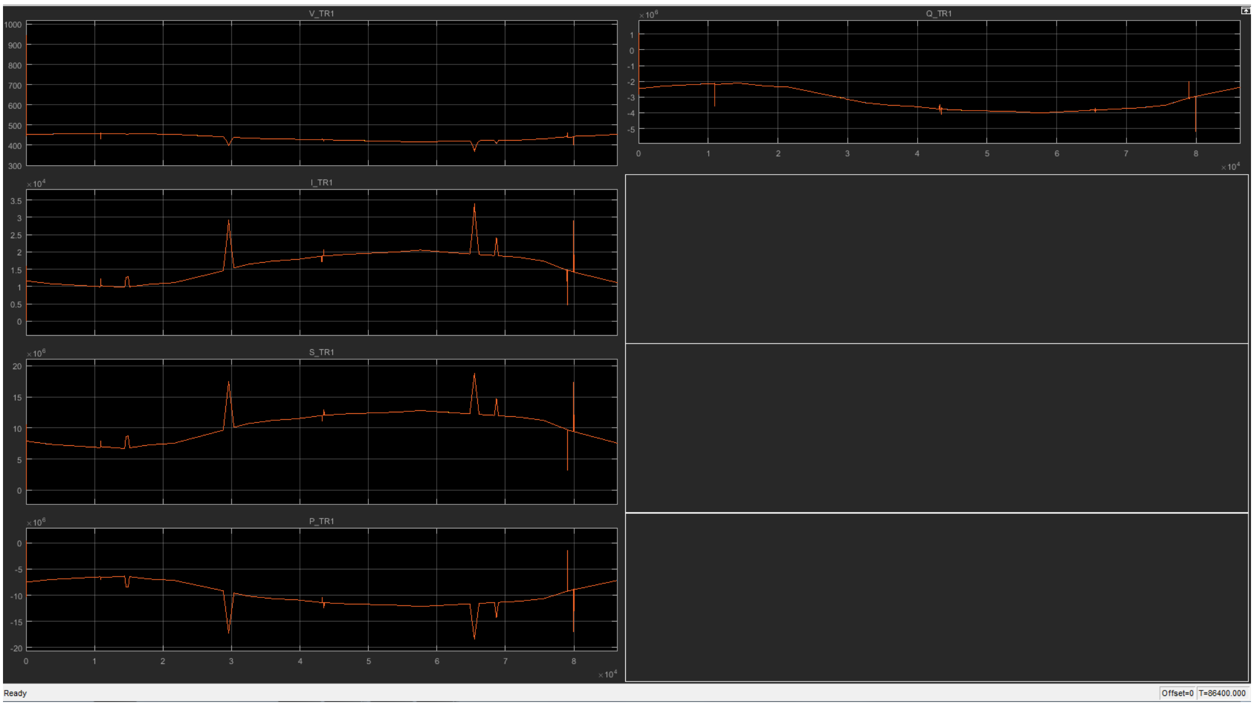
Results for 16 MW of Electric Vehicles with 12 MW of residential load



Results for 20 MW of Electric Vehicles with 4 MW of residential load

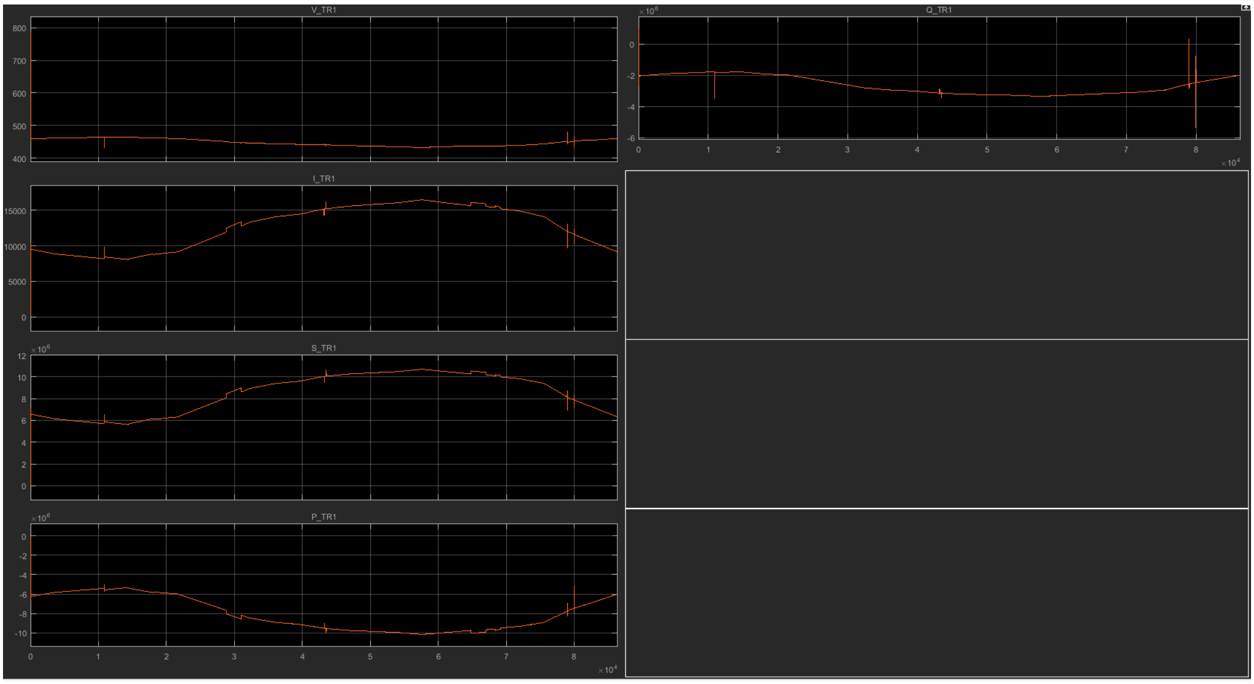


Results for 20 MW of Electric Vehicles with 8 MW of residential load

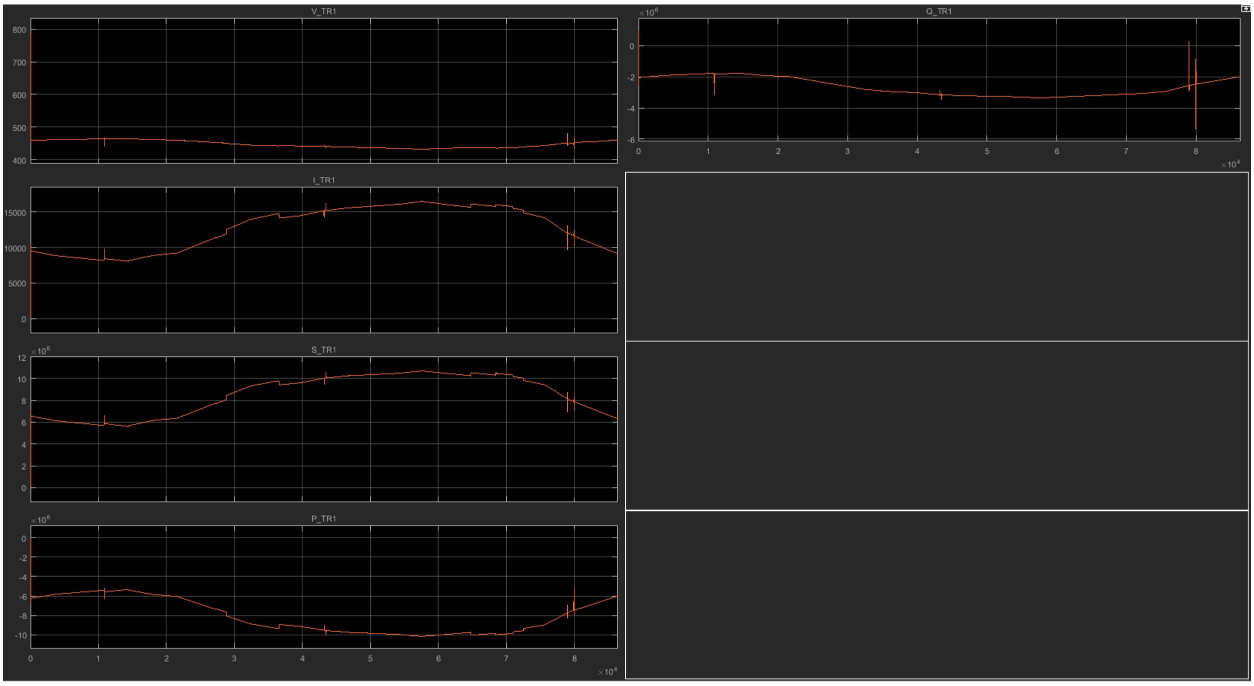


Results for 20 MW of Electric Vehicles with 12 MW of residential load

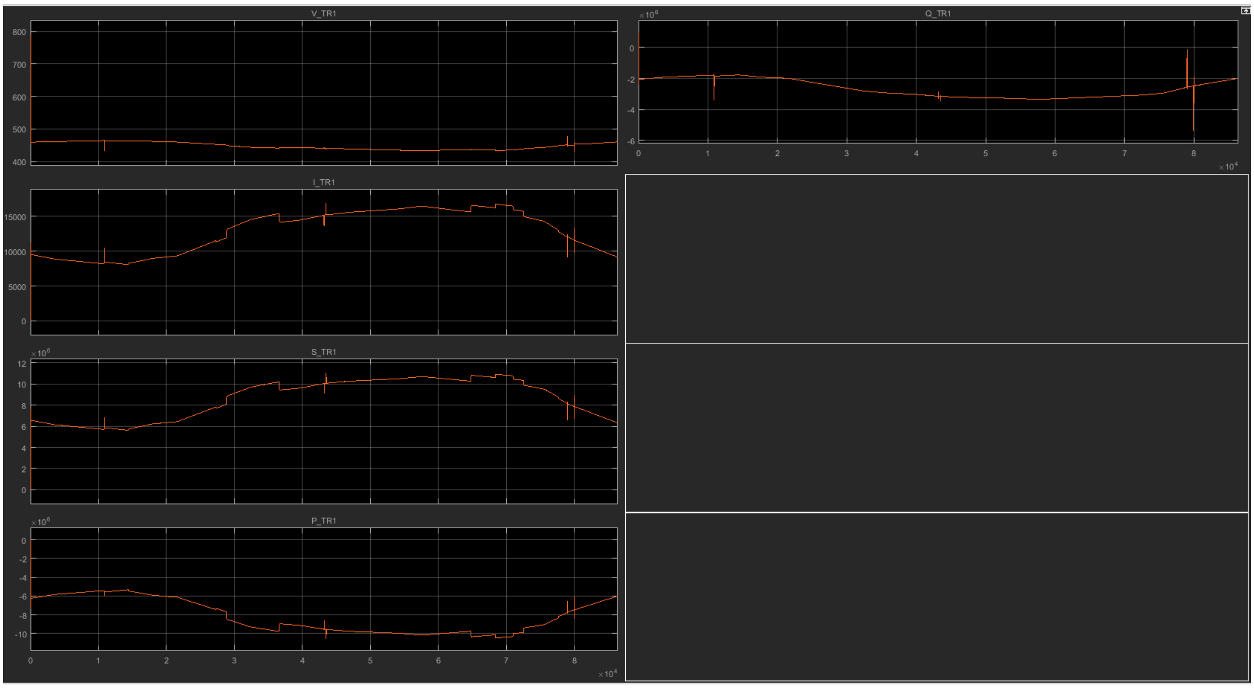
Results for Case 4



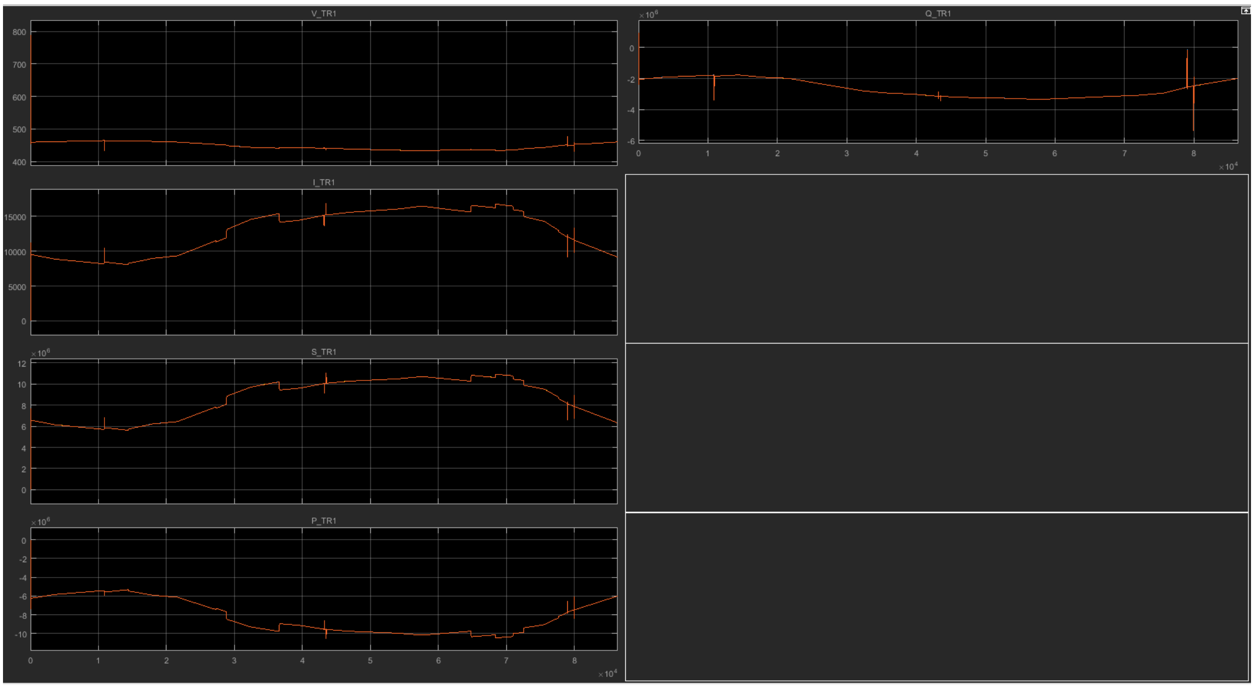
Simulation results for Case 4 Scenario 1



Simulation results for Case 4 Scenario 2

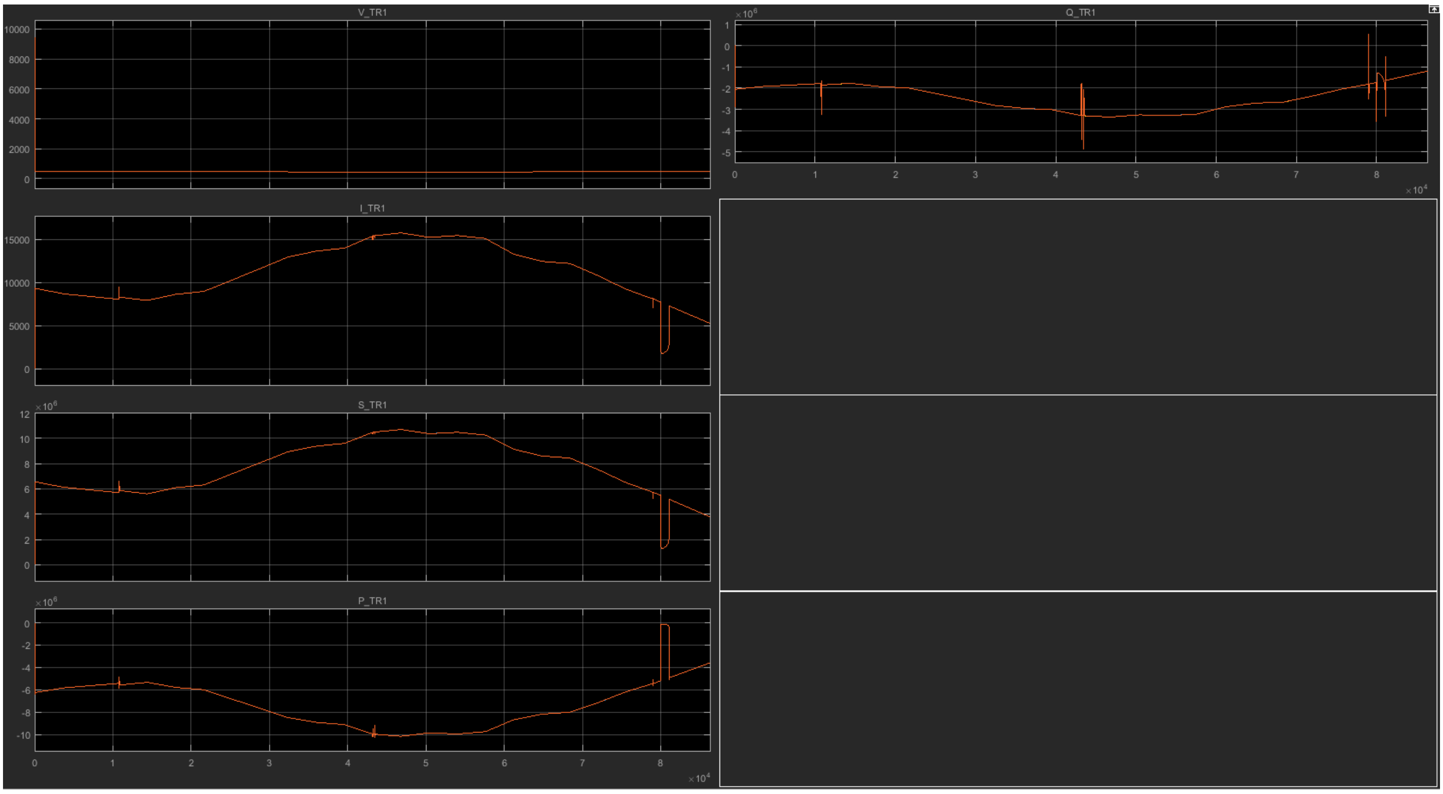


Simulation results for Case 4 Scenario 3

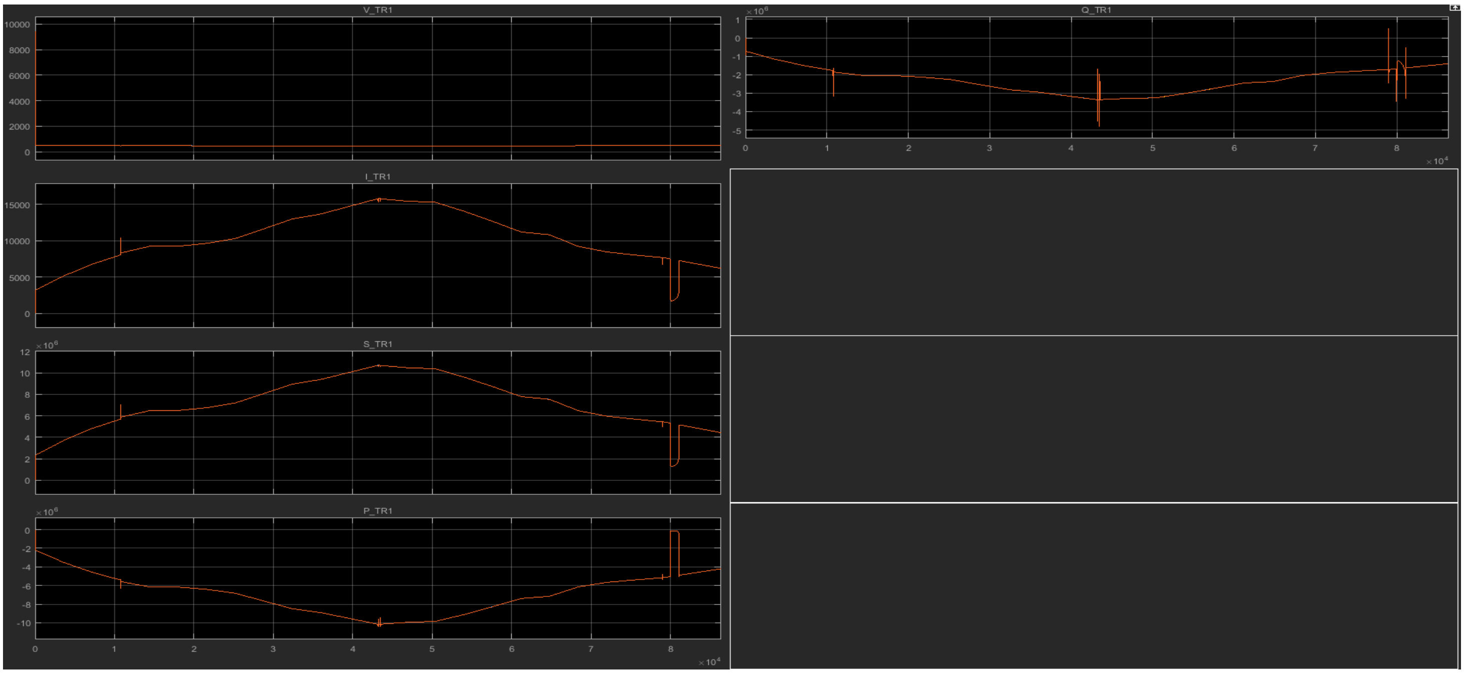


Simulation results for Case 4 Scenario 4

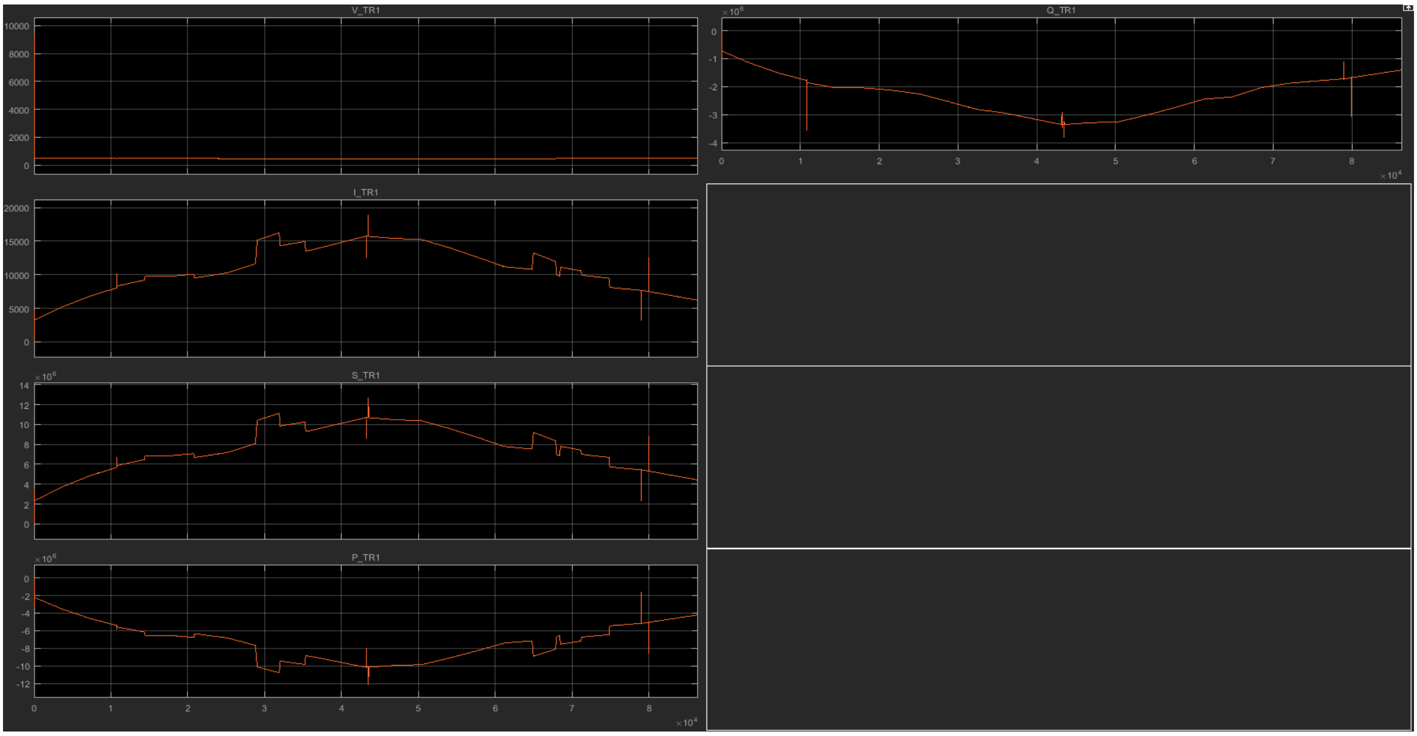
Simulation results for Commercial feeder



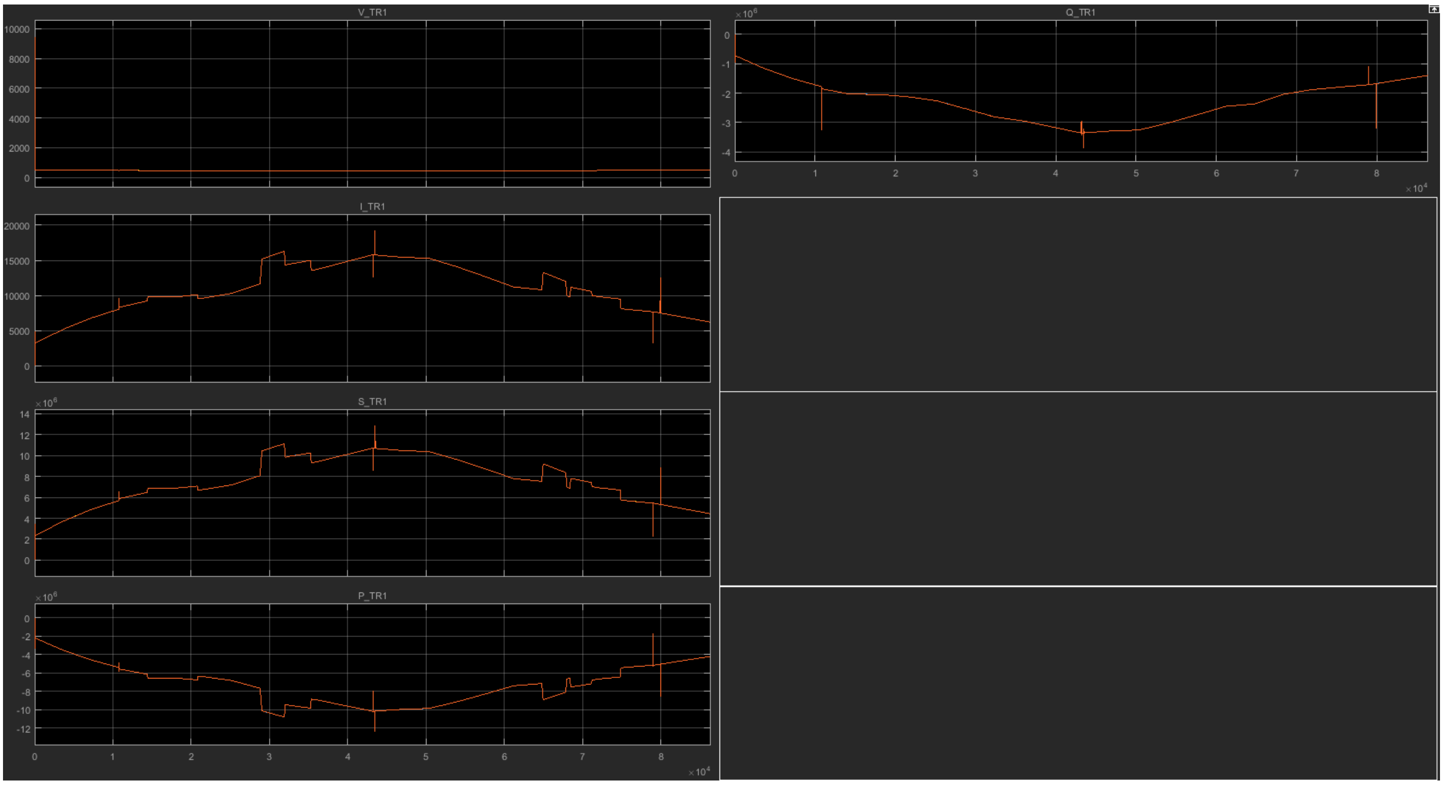
Results observed for baseline commercial load



Result for commercial load (Impedance)



Results for commercial integrated with EV load



Results for Commercial Load with EV load (Impedance)

Annexure V: Draft Franchisee Agreement for setting up EV Charging Infrascructure

[Draft Model Template]

This AGREEMENT entered into on this ________day of _________Two Thousand _____________ **between**____ having its registered office at ________________________ (herein after referred to as **Distribution Licensee** which expression shall unless repugnant to the context or meaning thereof include its successors and permitted assigns) as party of the **First part,**

And

____ having its registered office at __________________ (herein after referred to as **Franchisee (Electric Vehicles Charging Infrastructure)** which expression shall unless repugnant to the context or meaning thereof include its successors and permitted assigns) as party of the

Second part.

Whereas the Ministry of Power, Government of India has stated an objective of supporting electric vehicles offtake by consumers and to enable such a process has advised the Distribution Licensees to create Electric Vehicles Charging Infrastructure on their own or by creating franchisees.

NOW, THEREFORE, IN VIEW OF THE FOREGOING PREMISES AND IN CONSIDERATION OF THE MUTUAL COVENANTS AND CONDITIONS HEREIN SET- FORTH, BOTH PARTIES HEREBY AGREE AS FOLLOWS:

1. DEFINITION OF TERMS

For the purpose of this Franchise Agreement, and all Exhibits attached hereto, the following terms, phrases, and their derivations shall have the meanings given below unless the context clearly mandates a different interpretation. Where the context so indicates, the present tense shall imply the future tense, words in plural include the singular, and words in the singular include the plural. The word "shall" is always mandatory and not merely directory. The definitions are applicable regardless of whether the term is capitalized.

1.1 "Act/Statutory provisions" means application of its provisions and amendments if any thereto and /or Rules, Guidelines, Circulars, Instructions issued there under by the Government of India/ State Government.

1.2 "Annual Accounts" means the accounts of the franchised business prepared by the Franchisee in the manner as may be prescribed by the Distribution Licensee.

1.3 "Complaint" means any written or electronic correspondence expressing dissatisfaction with the products, services, or customer service of the Franchisee.

1.4 "Distribution" means the supply and conveyance of electricity by means of distribution system.

1.5 "Distribution system" means the system of wires and associated facilities, which facilitates connection to the point of connection of the installation of the consumer.

1.6 "Distribution system operating standards" means the standards related to the franchisee operation of its distribution system as provided by the Distribution Licensee to the Franchisee.

1.7 "Document" or "Records" means written or graphic materials, however produced or reproduced, or any other tangible permanent record, including records maintained by computer or other electronic or digital means, maintained by the Franchisee in the ordinary course of conducting its business.

1.8 "Electric Vehicles Charging Infrastructure" or "EVCI" means provision of adequate infrastructure that is created by the Franchisee for supply of electricity at retail tariff prescribed from time to time in the Tariff Orders issued by State Electricity Regulatory Commissions and "Electric Vehicles Charging Infrastructure Operator" means "EVCI Operator"

1.9 "Franchise" means the right granted by the Distribution Licensee to operate and maintain the Electric Vehicles Charging Infrastructure within the franchise area as embodied in this agreement for providing power supply to the consumers within the franchise area.

1.10 "Franchise Agreement" or "Agreement" means this contract and any amendments, exhibits or appendices hereto.

1.11 "Franchisee" means a person or an agency or a company authorised by the distribution licensee to set-up Electric Vehicles Charging Infrastructure on its behalf within area of supply of the distribution company; hereinafter Franchisee also refers to Electric Vehicles Charging Infrastructure Operator means the _______ (Name of Project Developer) who shall develop and operate Electric Vehicles Charging Infrastructure. Distribution Licensee reserves the right to appoint multiple and non-exclusive Franchisees within its area of supply.

1.12 "Franchised Business" means the Authorized business of the Electric Vehicles Charging Infrastructure Operator for selling of electricity in the franchise area for the purposes of charging electric vehicles.

1.13 "Gross Revenues" means all revenue derived directly or indirectly by the Electric Vehicles Charging Infrastructure Operator.

1.14 "Major Incident" means as incident associated with the Generation, Distribution and Retail Supply of electricity in the Franchise Area which results in a significant interruption of service, substantial damage to equipment, or loss of life or significant injury to human beings and shall include any other incident which the Distribution Licensee expressly declares to be a major incident.

1.15 “Normal operating conditions” means service conditions within the control of Electric Vehicles Charging Infrastructure Operator. Those conditions that are not within the control of Electric Vehicles Charging Infrastructure Operator include, but not limited to, natural disasters, civil disturbances, power outages, telephone network outages, and severe or unusual weather conditions as detailed under Section 12.3

1.16 “Project Area” means specific area rented, leased or owned by the Electric Vehicles Charging Infrastructure Operator; at which location the electricity is proposed to be sold to the Electric Vehicles owners.

1.17 "Public Rights-of-Way" means the surface, the air space above the surface, and the area below the surface of any public street, highway, lane, path, alley, sidewalk, bridge, tunnel, parkway, waterway, easement, or similar property within the franchise area, which, consistent with the purposes for which it was dedicated, may be used for the purpose of installing and maintaining the System. No reference herein to a "Public Right-of-Way" shall be deemed to be a representation or guarantee by the Distribution Licensee that its interest or other right to control the use of such property is sufficient to permit its use for such purposes, and Electric Vehicles Charging Infrastructure Operator shall be deemed to gain only those rights to use as are properly in the Distribution Licensee and as the Distribution Licensee may have the right and power to give.

1.18 "System Outage" means electricity supply Interruption.

2. GRANT OF FRANCHISE

2.1 Grant of Franchise

Subject to the terms and conditions of this Agreement and the Electricity Act, 2003, the Distribution Licensee hereby agrees that the Electric Vehicles Charging Infrastructure Operator may sell electricity to the Electric Vehicles Owners/Operators and also operate and maintain the electricity distribution system within the boundary area of the Electric Vehicles Charging Infrastructure, for the purpose of providing electricity to Electric Vehicles Owners/Operators. The Electric Vehicles Charging Infrastructure Operator shall operate as an agency and in no case shall be treated as a "Licensee". The Licensee reserves the right to appoint multiple franchisees to develop EV charging infrastructure within its Licence area.

2.2 Development of Infrastructure and its ownership:

The Electric Vehicles Charging Infrastructure Operator shall be permitted to develop electricity distribution infrastructure required for the purposes of charging electric vehicles. Electric Vehicles Charging Infrastructure Operator shall develop the infrastructure at its own cost and shall be the owner of the electricity distribution infrastructure within the franchise area created by them through their own resources in the course of its operation only for the purposes of electric vehicles charging.

2.3 Source of Power:

The source of power to the Electric Vehicles Charging Infrastructure Operator shall be the grid, sourced directly at a bulk supply tariff from the Distribution licensee or through Open Access following norms set-out for those purposes separately.

2.4 Location of Electric Vehicles Charging Infrastructure:

The location of Electric Vehicles Charging Infrastructure shall be within the license area of the distribution licensee defined under Project Area.

2.5 Duration of Franchise:

The term of this Franchise, and all rights, privileges, obligations, and restrictions pertaining thereto, shall be up to the life of the Electric Vehicles Charging Infrastructure as determined by the State Electricity Regulatory Commission or until the end of rent or lease or ownership of the Project Area, whichever is earlier, from the effective date of this Franchise.

2.6 Effective Date:

The Effective Date of this Franchise shall be (indicate date), subject to approval by the Distribution Licensee and its acceptance by the Electric Vehicles Charging Infrastructure Operator, provided that if the Electric Vehicles Charging Infrastructure Operator fails to accept the Franchise in writing within thirty (30) days following the communication of written approval by the Distribution Licensee in this regard, it shall be deemed to be accepted by Electric Vehicles Charging Infrastructure Operator in line with its application filed for seeking grant of Franchise.

2.7 Effect of Acceptance:

By accepting the Franchise and executing this Franchise Agreement, the Electric Vehicles Charging Infrastructure Operator:

(A) Accepts and agrees to comply with each applicable provision of this Agreement and, subject to relevant provisions of the Electricity Act, 2003;

(B) Agrees that it would not oppose intervention by the Distribution Licensee in the interest of effective power supply system in other parts of the license area.

2.8 The Electric Vehicles Charging Infrastructure Operator shall comply with the Regulations, Orders and Directions issued by the Distribution Licensee/SERC time to time and shall also act, at all times, in accordance with the terms and conditions of this Agreement.

2.9 It is the intent of both the parties that each party shall enjoy all rights and be subject to all obligations of this Franchise Agreement for the entire term of the Franchise and to the extent any provisions have continuing effect, after its expiration.

3. ACTIVITIES OF THE ELECTRIC VEHICLES CHARGING INFRASTRUCTURE OPERATOR

3.1 The Electric Vehicles Charging Infrastructure Operator shall be responsible for activity related to charging vehicles in the Franchise area.

3.2 The Electric Vehicles Charging Infrastructure Operator shall have to install and operate charging infrastructure to supply of electricity to Electric Vehicles users.

3.3 The Electric Vehicles Charging Infrastructure Operator shall have to develop electricity distribution infrastructure in the Franchise area at its own expenses.

Provided that Electric Vehicles Charging Infrastructure Operator shall comply with performance standards for development of distribution infrastructure.

3.4 The Electric Vehicles Charging Infrastructure Operator shall be allowed to procure power through open access provided that it complies with applicable Open Access Regulations.

3.5 The Electric Vehicles Charging Infrastructure Operator shall be responsible for all kinds of electricity billing related activity in franchise area like electricity metering, meter reading, electricity billing and bill collection.

3.5 The Electric Vehicles Charging Infrastructure Operator shall not, without the general or special approval of the Distribution Licensee:

(A) Resell electricity to any Consumers or otherwise for any purposes other than electric vehicles; or

(B) purchase or otherwise acquire electricity for distribution except in accordance with this Agreement and on the tariffs and terms and conditions as may be approved by the Distribution Licensee; or

(C) undertake any transaction to acquire, by purchase or takeover or otherwise, the Distribution Licensee of any other Supplier; or

(D) merge with any other entity; or

(E) transfer – by sale, lease, exchange or otherwise – the infrastructure assets of the Distribution Licensee, either in whole or any part thereof; or

(F) enter into any agreement or arrangement with any other person to get any part of the franchised business undertaken (with the exception of Co-operative), provided that any such agreement or arrangement shall be subject to the terms and conditions of this Agreement including such other terms and conditions that may be imposed by the Distribution Licensee; Further provided that the Electric Vehicles Charging Infrastructure Operator shall continue to have the overall responsibility for the due performance, by such other person and a breach of any of the terms and conditions of this Agreement by such other person shall be deemed to be a breach by the Electric Vehicles Charging Infrastructure Operator.

4. TECHNICAL CONDITIONS

4.1 Power Distribution:

(A) The Electric Vehicles Charging Infrastructure Operator shall always ensure supply of electrical energy to the Consumers

4.2 Compliance with Standards:

(A) The Electric Vehicles Charging Infrastructure Operator shall take all reasonable steps to ensure that all Consumers within the franchise area receive a safe, economical and reliable supply of electricity as defined in the Standards specified by the concerned SERC.

(B) The Electric Vehicles Charging Infrastructure Operator shall plan and operate the Distribution System to ensure that, subject to the availability of adequate power of appropriate quality, the Distribution System is capable of providing Consumers with a safe, reliable and efficient Supply of electricity.

(C) The Electric Vehicles Charging Infrastructure Operator shall undertake that adequate arrangements for supply of electricity in the franchise area in consultation and co-ordination with the Distribution Licensee.

4.3 Security Standards, Distribution System Operating Standards, Overall Performance Standards:

(A) The Electric Vehicles Charging Infrastructure Operator shall comply with the same practices which are followed by the Distribution Licensee with such modifications as may be permitted by the Distribution Licensee with regard to Security Standards and Distribution System Operating Standards until any new Security Standards and Distribution System Operating Standards are proposed by the Distribution Licensee

(B) If the Electric Vehicles Charging Infrastructure Operator fails to meet the Standards specified by the Distribution Licensee, without prejudice to any penalty that may be imposed or prosecution initiated, the Electric Vehicles Charging Infrastructure Operator shall be liable to pay such compensation to the person affected as may be determined by the Distribution Licensee, after allowing the Electric Vehicles Charging Infrastructure Operator a reasonable opportunity of being heard.

(C) The Electric Vehicles Charging Infrastructure Operator shall conduct its franchised business in the manner which it considers to be best calculated to achieve the Overall Performance Standards in connection with provision of Supply services and the promotion of the efficient use of electricity by Consumers, as may be prescribed by the Distribution Licensee pursuant to the Electricity Act, 2003.

4.4 Consumer Service:

(A) Electricity Supply Code:

The Electric Vehicles Charging Infrastructure Operator shall

(i) Comply with the relevant provisions of the Electricity Supply Code (as may be applicable for Electric Vehicles Charging Infrastructure) as approved by the relevant SERC.

(ii) Bring to the notice of the Consumers the existence of the Supply Code (and conditions of supply), including its substantive revision and their right to inspect or obtain a copy in its latest form;

(iii) Make available a copy of the Code (and conditions of supply) revised from time to time, for inspection by the public during normal working hours; and

(iv) Provide free of charge a copy of the Code (and conditions of supply) as revised from time to time to each new Consumer and to any other person who requests it at a price not exceeding the cost of duplicating it.

(B) Consumer Complaint Handling Procedure:

The Electric Vehicles Charging Infrastructure Operator shall comply with the Complaint Handling Procedure (as may be applicable for Electric Vehicles Charging Infrastructure) approved by the Distribution Licensee/SERC. The Electric Vehicles Charging Infrastructure Operator shall:

(i) Make available, on demand, a copy of the Complaint Handling Procedure, revised from time to time, for inspection by the public at each of the relevant premises during normal working hours; and

(ii) provide free of charge a copy of the Procedure revised from time to time to each new Consumer, and to any other person who requests for it at a price not exceeding the cost of duplicating it.

(C) Consumer’s Right to Information:

The Electric Vehicles Charging Infrastructure Operator, on request of the consumer, to the extent that is reasonably available to the Electric Vehicles Charging Infrastructure Operator, shall provide:

(i) Information on all services provided by the Electric Vehicles Charging Infrastructure Operator including information on the charges, which may be available to the consumers;

(ii) Information on meter readings for the electricity services provided to the consumer by the Electric Vehicles Charging Infrastructure Operator; and

(iii) Information on the status of the consumer’s account with the Electric Vehicles Charging Infrastructure Operator

(D) Consumer Rights-Discrimination Prohibited:

All the Tariff rates and charges for the consumers in Project Area shall be as applicable to the other consumers of Distribution Licensee belonging to similar consumer categories and should be non-discriminatory. Electric Vehicles Charging Infrastructure Operator shall establish similar rates and charges for all Consumers receiving similar services, regardless of race, colour, religion, age, sex, marital or economic status, sexual orientation and creed.

4.5 Provision of Information to the Distribution Licensee:

(A) The Electric Vehicles Charging Infrastructure Operator shall furnish to the Distribution Licensee without any delay such information, documents and details related to the Generation and Distribution Business of the Electric Vehicles Charging Infrastructure Operator, as the Distribution Licensee may require for its own purposes.

(B) The Distribution Licensee may, at anytime during the subsistence of this Agreement, authorize any Person(s) to inspect, verify and audit the performance, records and accounts of the Electric Vehicles Charging Infrastructure Operator and the Electric Vehicles Charging Infrastructure Operator shall be obliged to extend all cooperation, assistance and facilities, as may be required, to such authorized Person(s).

(C) The Electric Vehicles Charging Infrastructure Operator shall notify the Distribution Licensee of any Major Incident affecting any part of the Distribution System that has occurred and shall at the earliest possible and in any event, by no later than 15 days or such period as may be extended by the Distribution licensee from the date of such Major Incident. The Electric Vehicles Charging Infrastructure Operator shall also submit a report to the Distribution Licensee giving full details of the facts within the knowledge of the Electric Vehicles Charging Infrastructure Operator regarding the incident and its cause.

(D) The decision of the Distribution Licensee as to what is a Major Incident shall be final.

(E) The Distribution Licensee at its own discretion may require the submission of a report on any incident or incidents to be prepared by an independent Person at the expense of the Electric Vehicles Charging Infrastructure Operator to be included as an expense in the determination of aggregate revenues made in accordance with Section 5 of this Agreement.

4.6 Obligation to Connect Consumers:

(A) Subject to the other provisions of this Agreement, the Electric Vehicles Charging Infrastructure Operator shall have the following obligations:

(i) Subject to the provisions of Electricity Act, 2003, the Electric Vehicles Charging Infrastructure Operator shall, based on a desire by the Consumer, give the necessary permission to the Consumers.

(ii) It shall be the duty of the Electric Vehicles Charging Infrastructure Operator to provide, if required, requisite accessories or electric plant or electric line for giving electric supply to the Consumers specified in sub-clause (i) above, Provided that no person shall be entitled to demand, or to continue to receive, from the Electric Vehicles Charging Infrastructure Operator a supply of electricity unless he has agreed to pay to the Electric Vehicles Charging Infrastructure Operator such price as may be determined by the Distribution Licensee for the portion beyond the point of electricity access as defined under Section 1.9.

(D) Subject to the provisions of the Electricity Act, 2003 and such conditions as may be specified by the Distribution Licensee under section 4.5 of this Agreement, the Electric Vehicles Charging Infrastructure Operator may refuse to supply, or may disconnect the supply of electricity to any Consumer.

4.7 Obligation to Supply and Power Supply Planning Standards:

(A) The Electric Vehicles Charging Infrastructure Operator shall take all necessary steps to ensure that all Consumers connected to the Electric Vehicles Charging Infrastructure Operator's Distribution System receive a safe, economical and reliable Supply of electricity as provided in the performance standards referred to in this Agreement, the Consumer Rights Statement and the Complaint Handling Procedures, except where:

(i) the Electric Vehicles Charging Infrastructure Operator discontinues Supply to certain Consumers under the relevant provisions of the Electricity Laws for the reason of neglect or refusal to pay the charges due from the Consumer to the Electric Vehicles Charging Infrastructure Operator or in accordance with the Regulations contemplated under Section 4.5; or

(ii) the Electric Vehicles Charging Infrastructure Operator regulates the Supply to Consumers as may be directed by the Distribution Licensee.

5. CONSUMER TARIFF

5.1 Consumer Tariff Determination:

Consumer Tariff applicable for the consumers of the Electric Vehicles Charging Infrastructure Operator shall be same as applicable to the specific category of consumers of Distribution Licensee covered under a special category of tariffs relevant to electric vehicles charging, which includes base tariff same as Average Cost to Supply and a cap set-out in the Tariff Orders, which shall include provisioning for investments, depreciation, debt servicing, depreciation, Operation and Maintenance expenses and Return on Equity; or as specified by the SERC from time-to-time. The cross subsidy surcharge for the consumers of EV Charging infrastructure shall be waived off, should the power is procured through open access.

The Electric Vehicles Charging Infrastructure Operator shall be responsible to bill and collect the revenue from consumers and shall also be allowed to retain the revenue from the

Consumers, subject to any adjustment against any amount payable by the Distribution Licensee to Electric Vehicles Charging Infrastructure Operator.

5.2 Powers of Electric Vehicles Charging Infrastructure Operator:

For Revenue Realization, Meter Tampering etc. Subject to the provision of the Electricity Laws and the Rules framed there under and the applicable Regulations, the Electric Vehicles Charging Infrastructure Operator shall have the power and authority, on behalf of the Distribution Licensee, to take appropriate actions for:

(i) Metering at the point of supply of electricity;

(ii) Electricity billing and bill collection;

(iii) Revenue realization;

(iv) Prosecution for theft – of power; equipment or appliance;

(v) Prevention of meter tampering;

(vi) Prevention of diversion of electricity, and

(vii) Prevention of the unauthorized use of electricity;

(viii) Damage to public property; and

(ix) All such similar matters affecting electricity distribution.

6. TERMINATION AND BUY OUT

6.1 Termination:

This Franchisee Agreement shall automatically stand terminated in case the Electric Vehicles Charging Infrastructure Operator fails to service the consumers or fails to comply with the supply standards covered under Clause 4.7.

6.2 Buy Out:

Upon termination of Franchisee Agreement, the Distribution Licensee will acquire the distribution infrastructure developed by the Electric Vehicles Charging Infrastructure Operator and compensate Electric Vehicles Charging Infrastructure Operator at the prevalent book value of the asset or reassign the Franchise to other entity desirous of Electric Vehicles Charging Infrastructure Franchisee business.

7. INSURANCE

7.1 Insurance:

(A) The Electric Vehicles Charging Infrastructure Operator shall maintain in full force and effect, at its own cost and expense, during the term of the Franchise**,** the insurance for the value as may be indicated by the Distribution Licensee based on the depreciated cost of the electrical infrastructure.

(B) Such insurance shall be non-cancellable except upon thirty (30) days prior written notice to the Distribution Licensee. If the insurance is cancelled or materially altered so as to be out of compliance with the requirements of this section within the term of this Franchise, Electric Vehicles Charging Infrastructure Operator shall provide a replacement policy. Electric Vehicles Charging Infrastructure Operator shall maintain continuous uninterrupted insurance coverage, in at least the amounts required, for the duration of this Franchise.

8. AUDIT AND ACCOUNTS

8.1 Audit:

Electric Vehicles Charging Infrastructure Operator will allow for yearly audit of assets and inventories within the Franchise Area by Distribution Licensee.

Electric Vehicles Charging Infrastructure Operator shall allow yearly audit of the billing data & bill collection data including the system and database and consumer service centre's operated within the scope of the Franchise Area.

Electric Vehicles Charging Infrastructure Operator shall also comply with all reporting formats and data requirements prescribed by the Auditors.

8.2 Accounts:

(A) The financial year of the Electric Vehicles Charging Infrastructure Operator shall run from the first of April to the following thirty-first of March.

(B) The Electric Vehicles Charging Infrastructure Operator shall, in respect of the Franchised Business:

(i) keep such accounting records as would be required to be kept in respect of each such business so that the revenues, costs, assets, liabilities, reserves and provisions of, or reasonably attributable to the Franchised Business are separately identifiable in the books of the Electric Vehicles Charging

Infrastructure Operator, from those of Other Business in which the Electric Vehicles Charging Infrastructure Operator may be engaged;

(ii) prepare on a consistent basis from such accounting records and deliver to the Distribution Licensee:

a) the Accounting Statements;

b) in respect of the first six months of each financial year, an interim un-audited profit and loss account, cash flow statement, funds flow statement and provisional balance sheet;

c) in respect of the Accounting Statements prepared in accordance with this Section with separate accounting information pertaining to supply of electricity, an Auditor's report for each financial year stating whether in their opinion, these statements have been properly prepared in accordance with this Section and give a true and fair view of the revenues, costs, assets, liabilities, reserves and provisions of, or reasonably attributable to such businesses to which the statements relate; and

d) a copy of each interim un-audited profit and loss account not later than three months after the end of the period to which it relates, and copies of the Accounting Statements and Auditor's report not later than nine months after the end of the financial year to which they relate.

(C) Accounting Statements under Section 8.2(B) shall be prepared in accordance with generally accepted Indian accounting standards and/or as may be prescribed by the Distribution Licensee.

(D) References in this Section to costs or liabilities of, or reasonably attributable to the franchised business shall be construed as excluding taxation, and capital liabilities which do not relate principally to such business and interest thereon.

(E) The Distribution Licensee may, from such time it considers appropriate, require the Electric Vehicles Charging Infrastructure Operator to comply with the provisions of this Section 8.2(A) to 8.2(D) above treating the distribution business of the Electric Vehicles Charging Infrastructure Operator as separate and distinct businesses.

(F) Notwithstanding anything contained in this Section, whenever deemed fit, the Distribution Licensee may require the submission of a report prepared by an independent Auditor at the expense of the Electric Vehicle Charging Infrastructure Operator to be included as an expense in the determination of aggregate revenues made in accordance with Section 5 of this Agreement.

9. RECORDS:

Electric Vehicles Charging Infrastructure Operator shall maintain Records of Generation, Distribution, Operations, Electricity Billing and Revenue Collection that are open and accessible to the Distribution Licensee. The Distribution Licensee shall have the right to inspect such Records of the Electric Vehicles Charging Infrastructure Operator as are reasonably necessary.

10. REMEDIES FOR NON-COMPLIANCE

10.1 Termination:

(A) In the event of a material breach of this Franchise by the Electric Vehicles Charging Infrastructure Operator, the Distribution Licensee may, without limitation, exercise all rights and remedies provided for herein or otherwise available under the law, including termination of the Franchise. Without limitation, the following shall constitute material breaches of this Franchise:

(i) The Electric Vehicles Charging Infrastructure Operator 's failure or refusal to pay any required amount payable to the Distribution Licensee.

(ii) Gross failure by Electric Vehicles Charging Infrastructure Operator to provide required services desired under this agreement.

(B) In the event the Distribution Licensee intends to terminate this Franchise pursuant to the previous subsection, the Distribution Licensee shall provide a written notice to cure, identifying the nature of the breach with reasonable specificity, and advising Electric Vehicles Charging Infrastructure Operator of the Distribution Licensee's intent to terminate the Franchise.

(C) Any termination of this Franchise shall be by a written order issued by the Distribution Licensee; provided, however, before any such recourse is adopted, the Electric Vehicles Charging Infrastructure Operator must be provided an opportunity to be heard by the Distribution Licensee regarding such proposed action before any such action is taken.

11. RIGHTS-OF-WAY

11.1 Restoration of Property:

Whenever Electric Vehicles Charging Infrastructure Operator disturbs the surface of any Public Right-of Way for any purpose, the Electric Vehicles Charging Infrastructure Operator shall be responsible for restoration of such Public Right-of-Way and its surface within the area affected or otherwise damaged to at least a comparable or better condition as it was in prior to its disturbance by Electric Vehicles Charging Infrastructure Operator. Such restoration shall be undertaken as quickly as possible at the Electric Vehicles Charging Infrastructure Operator's own cost.

11.2 Maintenance and Workmanship:

(A) The Electric Vehicles Charging Infrastructure Operator shall carry out its operations as also maintenance of the infrastructure in such manner so as not to interfere with other public property or relevant public agencies.

(B) Electric Vehicles Charging Infrastructure Operator shall also carry out its operations in the manner so as to prevent injury to any person within the Distribution Licensee. All safety practices required by law shall be used during the operations of the Rural System Operator.

12. OTHER PROVISIONS

12.1 Compliance With Laws:

(C) Electric Vehicles Charging Infrastructure Operator shall comply with all applicable central / state laws and abide by the rules and regulations adopted or established pursuant to the Distribution Licensee's lawful authority.

12.2 Dispute Resolution:

(A) Any dispute between the Electric Vehicles Charging Infrastructure Operator and the Distribution Licensee arising out of / or in connection with this Agreement shall be first tried to be settled through mutual negotiation.

(B) In the event of such differences or disputes between the Electric Vehicles Charging Infrastructure Operator and the Distribution Licensee not settled through mutual negotiations within thirty days of such dispute, the matter shall be referred individually (or jointly) to the SERC for reference to settlement of differences or disputes by arbitration.

(C) The Electric Vehicles Charging Infrastructure Operator and the Distribution Licensee shall undertake to carry out any decision relating to such dispute without delay.

12.3 Force Majeure:

Neither party shall be responsible or liable for or deemed in breach hereof because of any delay or failure in the performance of its obligations hereunder (except for obligations to pay money due prior to occurrence of force majeure events under this Agreement) or failure to meet milestone dates due to any event or circumstance (a force majeure event) beyond the reasonable control of the party experiencing such delay or failure, including the occurrence of the following:

(a) Acts of God;

(b) Typhoons, floods, lightening, cyclones, Hurricanes, draught, famine, epidemic, or other natural calamities;

(c) Acts of war or Civil unrest;

(d) Any requirement, action or omission to act pursuant to any judgment or order of any court or judicial authority;

(e) Earthquakes, explosions.

12.4 Terms as to Suspension and Revocation:

It is a condition of this Agreement that the Electric Vehicles Charging Infrastructure Operator shall comply with all the Regulations, codes and standards and also orders and directions of the Distribution Licensee. When Distribution Licensee expressly states that an order subjects the Electric Vehicles Charging Infrastructure Operator to such compliance, failure to comply with that order will render this Agreement liable to revocation without prejudice to the Distribution Licensee's right to revoke this Agreement on any other applicable grounds.

12.5 Severability:

If any Section, provision or clause of this Electric Vehicles Charging Infrastructure Operator is held by a court of competent jurisdiction to be invalid or unenforceable, or is pre-empted by central or state laws or regulations, the remainder of this Franchise shall not be affected, except as is otherwise provided in this Franchise.

13. DOCUMENTS TO BE PROVIDED BY THE DISTRIBUTION LICENSEE TO ELECTRIC VEHICLES CHARGING INFRASTRUCTURE OPERATOR

13.1 Security Standards

13.2 Distribution System Operating Standards

13.3 Guidelines for Accounting Procedure

Dated this ___________ day of _________________, 20_______________.

_________________________________ _____________________________________

Electric Vehicles Charging Infrastructure Operator | Distribution Licensee

By: | By:

Title: | Title:

Annexure VI: Economic Impact Assessment Results

An overview of the final results, which will be detailed in the following sections.

Model results for tariff impact			
Scenario	**Business models**	**Growth options**	**Tariff Impact (Rs./kWh)**
NEMMP	**Scenario 1A**: Investments socialized to all the consumers	Low Growth	0.0007
		High Growth	0.0010
	Scenario 1B: Investments charged only to EV category sales	Low Growth	0.2810
		High Growth	0.2097
NEMMP+	**Scenario 1A**: Investments socialized to all the consumers	Low Growth	0.0013
		High Growth	0.0040
	Scenario 1B: Investments charged only to EV category sales	Low Growth	0.1912
		High Growth	0.1790

Summary:

1. Maximum tariff impact is seen in low growth NEMMP scenario when only EV users pay for the investments.
2. As per NEMMP ratio of number of chargers per vehicle stock is less in high growth scenario compared to the low growth resulting in higher tariff impact in case of low growth.

NEMMP Scenario

Vehicle stock as per NEMMP document			
	Low Growth	High growth	Sources
Type	**Vehicle Stock (NOS)**		
4 Wheelers	1,70,000	3,20,000	Table # 29 at page number 133 of NEMMP 2020 document
2 Wheelers	48,00,000	48,00,000	
Buses	300	700	
3 Wheelers	20,000	30,000	
Light Commercial Vehicles	30,000	50,000	

Charging Infrastructure as per NEMMP document					
	Low Growth		High growth		Sources
	Level 2	Fast DC	Level 2	Fast DC	
4 Wheelers	35,000	17,000	45,000	23,000	Exhibit # 42 to Exhibit # 49 at page numbers 112 to 115 of NEMMP 2020 document
2 Wheelers	-	-	-	-	
Buses	60	30	100	50	
3 Wheelers	2,000	1,000	4,000	2,000	
Light Commercial Vehicles	4,000	2,000	5,000	3,000	
Sub Total	41,060	20,030	54,100	28,050	
Cost per unit, INR (all types except buses)	36,000	2,25,000	36,000	2,25,000	Footnotes at the above referred exhibits
Cost per unit, INR (buses)	4,50,000	10,00,000	4,50,000	10,00,000	
Total Cost, INR Crores	150	453	199	635	
Grand total (INR Crore)	**603**		**834**		

Calculations related to annual electricity consumption from vehicle stock using public infrastructure					
Vehicle Stock	Average Distance Travelled (kms)	Electricity consumption, kWh/100km	Electricity consumption, kWh/km	Annual energy consumption in MkWh (MUs)	
				Low Growth	High growth
4 Wheelers	40000	36	0.36	2448	4608
2 Wheelers	8000	8	0.08	3072	3072
Buses	50000	175	1.75	26.25	61.25
3 Wheelers	25000	15	0.15	75	112.5
Light Commercial Vehicles	30000	36	0.36	324	540
Total with 2-wheelers				**5,945**	**8,394**
Total without 2-wheelers				**2,873**	**5,322**

Notes:

1. Average distance travelled is assumed based on interviews with the market players except for 4-wheelers. 4-wheelers' distance travelled number is assumed as 150 km/day for taxis and 50 km/day for other 4-wheelers. Weighted average works out to be 120 kms/day, which is multiplied by 330 days/year of travel.
2. Electricity consumption (kWh/100km) numbers are from Office Memorandum of Department of Heavy Industries dated 26 March 2015 (highest number of the range of values are considered here).

NEMMP+ Scenario

Vehicle stock in NEMMP+ scenario			
Type	Low Growth	High growth	Source
	Vehicle Stock (NOS)		
4 Wheelers	3,20,000	4,00,000	Assumption- NEMMP scenario numbers scaled up
2 Wheelers	48,00,000	48,00,000	Number same as NEMMP scenario
Buses	25,000	2,00,000	Assumption- with the focus on electrifying public transport, as announced by MoP recently
3 Wheelers	60,000	90,000	Tripled the numbers assumed in NEMMP, given the focus on this category
Light Commercial Vehicles	90,000	1,50,000	Assumption- NEMMP scenario numbers scaled up

Charging Infrastructure required for NEMMP + scenario					
	Low Growth		High growth		Sources
	Level 2	Fast DC	Level 2	Fast DC	
4 Wheelers	45,000	23,000	56,250	28,750	Calculations described in the Notes section
2 Wheelers	-	-	-	-	
Buses	5,000	2,500	40,000	20,000	
3 Wheelers	6,000	3,000	9,000	4,500	
Light Commercial Vehicles	12,000	6,000	20,000	10,000	
Sub Total	68,000	34,500	1,25,250	63,250	
Cost per unit, INR (all types except buses)	36,000	2,00,000	36,000	2,00,000	Target costs by industry players
Cost per unit, INR (buses)	2,50,000	6,00,000	2,50,000	6,00,000	
Total Cost, INR Crores	352	790	1,307	2,065	
Grand total (INR Crore)	**1141.8**		**3371.9**		

Notes:

1. Ratio of chargers to the number of vehicles in respective categories as assumed in NEMMP is used to determine the number of chargers for the Low growth scenario above. For the High growth scenario, percentage increase in vehicle stock as compared to the Low growth scenario times the number of chargers in the respective categories has been used.

Calculations related to annual electricity consumption from vehicle stock using public infrastructure					
Vehicle Stock	Average Distance Travelled (kms)	Electricity consumption, kWh/100km	Electricity consumption, kWh/km	Annual energy consumption in MkWh (MUs)	
				Low Growth	High growth
4 Wheelers	40000	36	0.36	4608	5760
2 Wheelers	8000	8	0.08	3072	3072
Buses	50000	175	1.75	2187.5	17500
3 Wheelers	25000	15	0.15	225	337.5
Light Commercial Vehicles	30000	36	0.36	972	1620
Total with 2-wheelers				**11,065**	**28,290**
Total without 2-wheelers				**7,993**	**25,218**

Notes:

1. Average distance travelled is assumed based on interviews with the market players except for 4-wheelers. 4-wheelers' distance travelled number is assumed as 150 km/day for taxis and 50 km/day for other 4-wheelers. Weighted average works out to be 120 kms/day, which is multiplied by 330 days/year of travel.
2. Electricity consumption (kWh/100km) numbers are from Office Memorandum of Department of Heavy Industries dated 26 March 2015 (highest number of the range of values are considered here).

Additional capacity requirement calculations, MW					
Scenario	Growth Option	MUs	Annual hours	PLF, %	MW
NEMMP	Low Growth	2,873	8760	60%	547
	High Growth	5,322	8760	60%	1013
NEMMP+	Low Growth	7,993	8760	60%	1521
	High Growth	25,218	8760	60%	4798

Tariff Impact Estimation

Tariff impact Estimation			
Particulars	**Unit**	**Value**	**Source**
Actual energy availability in the country 2016-17	MUs	11,35,334	LGBR report, CEA 2017-18
Annual growth rate	%	4%	
O&M Cost	% of capital cost	1%	
Escalation on O&M costs	%	5%	
Debt	% of capital cost	70%	MERC MYT Tariff Regulation, 2015
Equity	% of capital cost	30%	
Project Life	years	15	
Depreciation value base	% of capital cost	100%	
Rate of Depreciation	p.a.	5.28%	
Capital Parameters			
Normative Return on Equity	p.a.	15.50%	MERC MYT Tariff Regulation, 2015; MSEDCL Tariff Order (case no. 48 of 2016 dated 3 November 2016
Interest on Debt	p.a.	10%	
Interest on working capital	p.a.	14.75%	
Discount Rate	p.a.	10%	
Term of Loan	years	13	

Results of Cash Flows

NEMMP Low Growth Scenario

Scenario	Option	Tariff Impact (Rs./kWh)
Scenario 1A	Low Growth	₹0.0007
Scenario 1B	Low Growth	₹0.2809

Scenario 1A: Investments socialized to all the consumers																
Particulars	**Years**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Capital cost for installation	Rs. Crore	603														
Total consumption	MUs	11,35,334	11,80,747	12,27,977	12,77,096	13,28,180	13,81,307	14,36,560	14,94,022	15,53,783	16,15,934	16,80,572	17,47,795	18,17,706	18,90,415	19,66,031
Operation and Maintenance cost	Rs. Crore	6.0	6.3	6.6	7.0	7.3	7.7	8.1	8.5	8.9	9.4	9.8	10.3	10.8	11.4	11.9
Depreciation	Rs. Crore	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	94.6	94.6
Interest on Term Loan	Rs. Crore	42.2	39.0	35.8	32.7	29.5	26.3	23.1	19.9	16.7	13.6	10.4	7.2	4.0	0.8	0.0
Return on Equity	Rs. Crore	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
Total Fixed Cost	Rs. Crore	108.1	105.2	102.4	99.5	96.7	93.9	91.1	88.3	85.5	82.8	80.1	77.4	74.7	134.8	134.5
Discount Factor	Calculated	1	0.90909	0.82645	0.75131	0.68301	0.62092	0.56447	0.51316	0.46651	0.42410	0.38554	0.35049	0.31863	0.28966	0.26333
Total cost	Rs/kWh	0.0010	0.0009	0.0008	0.0008	0.0007	0.0007	0.0006	0.0006	0.0006	0.0005	0.0005	0.0004	0.0004	0.0007	0.0007
Levelized Tariff Impact	Rs/kWh	**₹0.00071**														
Interest on Loan																
Opening Balance	Rs. Crore	422.1	390.3	358.4	326.6	294.7	262.9	231.1	199.2	167.4	135.6	103.7	71.9	40.0	8.2	0.0
Constant Repayment	Rs. Crore	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	8.2	0.0
Closing Balance	Rs. Crore	390.3	358.4	326.6	294.7	262.9	231.1	199.2	167.4	135.6	103.7	71.9	40.0	8.2	0.0	0.0
Interest on Loan	Rs. Crore	42.2	39.0	35.8	32.7	29.5	26.3	23.1	19.9	16.7	13.6	10.4	7.2	4.0	0.8	0.0
Depreciation																
Opening Balance	Rs. Crore	603.0	571.2	539.3	507.5	475.6	443.8	412.0	380.1	348.3	316.5	284.6	252.8	220.9	189.1	94.6
Annual Depreciation	Rs. Crore	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	94.6	94.6
Closing Balance	Rs. Crore	571.2	539.3	507.5	475.6	443.8	412.0	380.1	348.3	316.5	284.6	252.8	220.9	189.1	94.6	0.0

Scenario 1B: Investments charged only to EV category sales																
Particulars	**Years**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Capital cost for installation	Rs. Crore	603														
Expected energy consumption from EVs	MUs	2,873.3	2,988.2	3,107.7	3,232.0	3,361.3	3,495.7	3,635.6	3,781.0	3,932.2	4,089.5	4,253.1	4,423.2	4,600.2	4,784.2	4,975.5
Operation and Maintenance cost	Rs. Crore	6.0	6.3	6.6	7.0	7.3	7.7	8.1	8.5	8.9	9.4	9.8	10.3	10.8	11.4	11.9
Depreciation	Rs. Crore	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	94.6	94.6
Interest on Term Loan	Rs. Crore	42.2	39.0	35.8	32.7	29.5	26.3	23.1	19.9	16.7	13.6	10.4	7.2	4.0	0.8	-
Return on Equity	Rs. Crore	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
Total Fixed Cost	Rs. Crore	108.1	105.2	102.4	99.5	96.7	93.9	91.1	88.3	85.5	82.8	80.1	77.4	74.7	134.8	134.5
Discount Factor	Calculated	1	0.90909	0.82645	0.75131	0.68301	0.62092	0.56447	0.51316	0.46651	0.42410	0.38554	0.35049	0.31863	0.28966	0.26333
Total cost	Rs/kWh	0.3763	0.3522	0.3294	0.3079	0.2876	0.2685	0.2505	0.2335	0.2175	0.2024	0.1883	0.1749	0.1624	0.2817	0.2704
Levelized Tariff Impact	Rs/kWh	**₹0.28090**														
Interest on Loan																
Opening Balance	Rs. Crore	422.1	390.3	358.4	326.6	294.7	262.9	231.1	199.2	167.4	135.6	103.7	71.9	40.0	8.2	0
Constant Repayment	Rs. Crore	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	8.2	0
Closing Balance	Rs. Crore	390.3	358.4	326.6	294.7	262.9	231.1	199.2	167.4	135.6	103.7	71.9	40.0	8.2	0.0	0
Interest on Loan	Rs. Crore	42.2	39.0	35.8	32.7	29.5	26.3	23.1	19.9	16.7	13.6	10.4	7.2	4.0	0.8	0
Depreciation																
Opening Balance	Rs. Crore	603.0	571.2	539.3	507.5	475.6	443.8	412.0	380.1	348.3	316.5	284.6	252.8	220.9	189.1	94.6
Annual Depreciation	Rs. Crore	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	94.6	94.6
Closing Balance	Rs. Crore	571.2	539.3	507.5	475.6	443.8	412.0	380.1	348.3	316.5	284.6	252.8	220.9	189.1	94.6	0.0

NEMMP High Growth Scenario

Scenario	Option	Tariff Impact (Rs./kWh)
Scenario 1A	High Growth	₹0.0010
Scenario 1B	High Growth	₹0.2097

Scenario 1A: Investments socialized to all the consumers																
Particulars	**Years**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Capital cost for installation	Rs. Crore	833.9														
Total consumption	MUs	11,35,334	11,80,747	12,27,977	12,77,096	13,28,180	13,81,307	14,36,560	14,94,022	15,53,783	16,15,934	16,80,572	17,47,795	18,17,706	18,90,415	19,66,031
Operation and Maintenance cost	Rs. Crore	8.3	8.8	9.2	9.7	10.1	10.6	11.2	11.7	12.3	12.9	13.6	14.3	15.0	15.7	16.5
Depreciation	Rs. Crore	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	130.8	130.8
Interest on Term Loan	Rs. Crore	58.4	54.0	49.6	45.2	40.8	36.4	32.0	27.6	23.1	18.7	14.3	9.9	5.5	1.1	0.0
Return on Equity	Rs. Crore	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8
Total Fixed Cost	Rs. Crore	149.5	145.5	141.6	137.6	133.7	129.8	125.9	122.1	118.3	114.5	110.7	107.0	103.3	186.4	186.0
Discount Factor	Calculated	1	0.90909	0.82645	0.75131	0.68301	0.62092	0.56447	0.51316	0.46651	0.42410	0.38554	0.35049	0.31863	0.28966	0.26333
Total cost	Rs/kWh	0.0013	0.0012	0.0012	0.0011	0.0010	0.0009	0.0009	0.0008	0.0008	0.0007	0.0007	0.0006	0.0006	0.0010	0.0009
Levelized Tariff Impact	Rs/kWh	**₹0.00098**														
Interest on Loan																
Opening Balance	Rs. Crore	583.7	539.7	495.7	451.6	407.6	363.6	319.6	275.5	231.5	187.5	143.4	99.4	55.4	11.3	0.0
Constant Repayment	Rs. Crore	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	11.3	0.0
Closing Balance	Rs. Crore	539.7	495.7	451.6	407.6	363.6	319.6	275.5	231.5	187.5	143.4	99.4	55.4	11.3	0.0	0.0
Interest on Loan	Rs. Crore	58.4	54.0	49.6	45.2	40.8	36.4	32.0	27.6	23.1	18.7	14.3	9.9	5.5	1.1	0.0
Depreciation																
Opening Balance	Rs. Crore	833.9	789.9	745.8	701.8	657.8	613.8	569.7	525.7	481.7	437.6	393.6	349.6	305.5	261.5	130.8
Annual Depreciation	Rs. Crore	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	130.8	130.8
Closing Balance	Rs. Crore	789.9	745.8	701.8	657.8	613.8	569.7	525.7	481.7	437.6	393.6	349.6	305.5	261.5	130.8	0.0

Scenario 1B: Investments charged only to EV category sales																
Particulars	**Years**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Capital cost for installation	Rs. Crore	833.9														
Expected energy consumption from EVs	MUs	5,321.8	5,534.6	5,756.0	5,986.2	6,225.7	6,474.7	6,733.7	7,003.1	7,283.2	7,574.5	7,877.5	8,192.6	8,520.3	8,861.1	9,215.5
Operation and Maintenance cost	Rs. Crore	8.3	8.8	9.2	9.7	10.1	10.6	11.2	11.7	12.3	12.9	13.6	14.3	15.0	15.7	16.5
Depreciation	Rs. Crore	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	130.8	130.8
Interest on Term Loan	Rs. Crore	58.4	54.0	49.6	45.2	40.8	36.4	32.0	27.6	23.1	18.7	14.3	9.9	5.5	1.1	-
Return on Equity	Rs. Crore	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8	38.8
Total Fixed Cost	Rs. Crore	149.5	145.5	141.6	137.6	133.7	129.8	125.9	122.1	118.3	114.5	110.7	107.0	103.3	186.4	186.0
Discount Factor	Calculated	1	0.90909	0.82645	0.75131	0.68301	0.62092	0.56447	0.51316	0.46651	0.42410	0.38554	0.35049	0.31863	0.28966	0.26333
Total cost	Rs/kWh	0.2810	0.2629	0.2459	0.2299	0.2148	0.2005	0.1870	0.1743	0.1624	0.1512	0.1406	0.1306	0.1213	0.2103	0.2019
Levelized Tariff Impact	Rs/kWh	**₹0.20973**														
Interest on Loan																
Opening Balance	Rs. Crore	583.7	539.7	495.7	451.6	407.6	363.6	319.6	275.5	231.5	187.5	143.4	99.4	55.4	11.3	0
Constant Repayment	Rs. Crore	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	11.3	0
Closing Balance	Rs. Crore	539.7	495.7	451.6	407.6	363.6	319.6	275.5	231.5	187.5	143.4	99.4	55.4	11.3	0.0	0
Interest on Loan	Rs. Crore	58.4	54.0	49.6	45.2	40.8	36.4	32.0	27.6	23.1	18.7	14.3	9.9	5.5	1.1	0
Depreciation																
Opening Balance	Rs. Crore	833.9	789.9	745.8	701.8	657.8	613.8	569.7	525.7	481.7	437.6	393.6	349.6	305.5	261.5	130.8
Annual Depreciation	Rs. Crore	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	130.8	130.8
Closing Balance	Rs. Crore	789.9	745.8	701.8	657.8	613.8	569.7	525.7	481.7	437.6	393.6	349.6	305.5	261.5	130.8	0.0

NEMMP+ Low Growth Scenario

Scenario	Option	Tariff Impact
Scenario 1A	Low Growth	₹0.0013
Scenario 1B	Low Growth	₹0.1912

Scenario 1A: Investments socialized to all the consumers																
Particulars	**Years**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Capital cost for installation	Rs. Crore	1141.8														
Total consumption	MUs	11,35,334	11,80,747	12,27,977	12,77,096	13,28,180	13,81,307	14,36,560	14,94,022	15,53,783	16,15,934	16,80,572	17,47,795	18,17,706	18,90,415	19,66,031
Operation and Maintenance cost	Rs. Crore	11.4	12.0	12.6	13.2	13.9	14.6	15.3	16.1	16.9	17.7	18.6	19.5	20.5	21.5	22.6
Depreciation	Rs. Crore	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	179.0	179.0
Interest on Term Loan	Rs. Crore	79.9	73.9	67.9	61.8	55.8	49.8	43.8	37.7	31.7	25.7	19.6	13.6	7.6	1.6	0.0
Return on Equity	Rs. Crore	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1
Total Fixed Cost	Rs. Crore	204.7	199.3	193.8	188.4	183.1	177.7	172.4	167.2	161.9	156.8	151.6	146.5	141.5	255.2	254.7
Discount Factor	Calculated	1.00000	0.90909	0.82645	0.75131	0.68301	0.62092	0.56447	0.51316	0.46651	0.42410	0.38554	0.35049	0.31863	0.28966	0.26333
Total cost	Rs/kWh	0.0018	0.0017	0.0016	0.0015	0.0014	0.0013	0.0012	0.0011	0.0010	0.0010	0.0009	0.0008	0.0008	0.0014	0.0013
Levelized Tariff Impact	Rs/kWh	**₹0.00135**														
Interest on Loan																
Opening Balance	Rs. Crore	799.3	739.0	678.7	618.4	558.1	497.8	437.5	377.3	317.0	256.7	196.4	136.1	75.8	15.5	0.0
Constant Repayment	Rs. Crore	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	15.5	0.0
Closing Balance	Rs. Crore	739.0	678.7	618.4	558.1	497.8	437.5	377.3	317.0	256.7	196.4	136.1	75.8	15.5	0.0	0.0
Interest on Loan	Rs. Crore	79.9	73.9	67.9	61.8	55.8	49.8	43.8	37.7	31.7	25.7	19.6	13.6	7.6	1.6	0.0
Depreciation																
Opening Balance	Rs. Crore	1141.8	1081.5	1021.2	960.9	900.7	840.4	780.1	719.8	659.5	599.2	538.9	478.6	418.4	358.1	179.0
Annual Depreciation	Rs. Crore	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	179.0	179.0
Closing Balance	Rs. Crore	1081.5	1021.2	960.9	900.7	840.4	780.1	719.8	659.5	599.2	538.9	478.6	418.4	358.1	179.0	0.0

Scenario 1B: Investments charged only to EV category sales																
Particulars	**Years**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Capital cost for installation	Rs. Crore	1141.8														
Expected energy consumption from EVs	MUs	7,992.5	8,312.2	8,644.7	8,990.5	9,350.1	9,724.1	10,113.1	10,517.6	10,938.3	11,375.8	11,830.9	12,304.1	12,796.3	13,308.1	13,840.4
Operation and Maintenance cost	Rs. Crore	11.4	12.0	12.6	13.2	13.9	14.6	15.3	16.1	16.9	17.7	18.6	19.5	20.5	21.5	22.6
Depreciation	Rs. Crore	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	179.0	179.0
Interest on Term Loan	Rs. Crore	79.9	73.9	67.9	61.8	55.8	49.8	43.8	37.7	31.7	25.7	19.6	13.6	7.6	1.6	-
Return on Equity	Rs. Crore	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1	53.1
Total Fixed Cost	Rs. Crore	204.7	199.3	193.8	188.4	183.1	177.7	172.4	167.2	161.9	156.8	151.6	146.5	141.5	255.2	254.7
Discount Factor	Calculated	1.00000	0.90909	0.82645	0.75131	0.68301	0.62092	0.56447	0.51316	0.46651	0.42410	0.38554	0.35049	0.31863	0.28966	0.26333
Total cost	Rs/kWh	0.2561	0.2397	0.2242	0.2096	0.1958	0.1828	0.1705	0.1589	0.1481	0.1378	0.1282	0.1191	0.1106	0.1918	0.1841
Levelized Tariff Impact	Rs/kWh	**₹0.19121**														
Interest on Loan																
Opening Balance	Rs. Crore	799.3	739.0	678.7	618.4	558.1	497.8	437.5	377.3	317.0	256.7	196.4	136.1	75.8	15.5	0
Constant Repayment	Rs. Crore	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	15.5	0
Closing Balance	Rs. Crore	739.0	678.7	618.4	558.1	497.8	437.5	377.3	317.0	256.7	196.4	136.1	75.8	15.5	0.0	0
Interest on Loan	Rs. Crore	79.9	73.9	67.9	61.8	55.8	49.8	43.8	37.7	31.7	25.7	19.6	13.6	7.6	1.6	0
Depreciation																
Opening Balance	Rs. Crore	1141.8	1081.5	1021.2	960.9	900.7	840.4	780.1	719.8	659.5	599.2	538.9	478.6	418.4	358.1	179.0
Annual Depreciation	Rs. Crore	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	179.0	179.0
Closing Balance	Rs. Crore	1081.5	1021.2	960.9	900.7	840.4	780.1	719.8	659.5	599.2	538.9	478.6	418.4	358.1	179.0	0.0

NEMMP+ High Growth Scenario

Scenario	Option	Tariff Impact
Scenario 1A	High Growth	₹0.0040
Scenario 1B	High Growth	₹0.1790

Scenario 1A: Investments socialized to all the consumers																
Particulars	**Years**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Capital cost for installation	Rs. Crore	3371.9														
Total consumption	MUs	11,35,334	11,80,747	12,27,977	12,77,096	13,28,180	13,81,307	14,36,560	14,94,022	15,53,783	16,15,934	16,80,572	17,47,795	18,17,706	18,90,415	19,66,031
Operation and Maintenance cost	Rs. Crore	33.7	35.4	37.2	39.0	41.0	43.0	45.2	47.4	49.8	52.3	54.9	57.7	60.6	63.6	66.8
Depreciation	Rs. Crore	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	528.7	528.7
Interest on Term Loan	Rs. Crore	236.0	218.2	200.4	182.6	164.8	147.0	129.2	111.4	93.6	75.8	58.0	40.2	22.4	4.6	0.0
Return on Equity	Rs. Crore	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8
Total Fixed Cost	Rs. Crore	604.6	588.5	572.4	556.5	540.6	524.9	509.2	493.7	478.3	462.9	447.8	432.7	417.8	753.7	752.3
Discount Factor	Calculated	1.00000	0.90909	0.82645	0.75131	0.68301	0.62092	0.56447	0.51316	0.46651	0.42410	0.38554	0.35049	0.31863	0.28966	0.26333
Total cost	Rs/kWh	0.0053	0.0050	0.0047	0.0044	0.0041	0.0038	0.0035	0.0033	0.0031	0.0029	0.0027	0.0025	0.0023	0.0040	0.0038
Levelized Tariff Impact	Rs/kWh	**₹0.00398**														
Interest on Loan																
Opening Balance	Rs. Crore	2360.3	2182.3	2004.3	1826.2	1648.2	1470.1	1292.1	1114.1	936.0	758.0	580.0	401.9	223.9	45.9	0.0
Constant Repayment	Rs. Crore	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	45.9	0.0
Closing Balance	Rs. Crore	2182.3	2004.3	1826.2	1648.2	1470.1	1292.1	1114.1	936.0	758.0	580.0	401.9	223.9	45.9	0.0	0.0
Interest on Loan	Rs. Crore	236.0	218.2	200.4	182.6	164.8	147.0	129.2	111.4	93.6	75.8	58.0	40.2	22.4	4.6	0.0
Depreciation																
Opening Balance	Rs. Crore	3371.9	3193.9	3015.8	2837.8	2659.8	2481.7	2303.7	2125.6	1947.6	1769.6	1591.5	1413.5	1235.5	1057.4	528.7
Annual Depreciation	Rs. Crore	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	528.7	528.7
Closing Balance	Rs. Crore	3193.9	3015.8	2837.8	2659.8	2481.7	2303.7	2125.6	1947.6	1769.6	1591.5	1413.5	1235.5	1057.4	528.7	0.0

Scenario 1B: Investments charged only to EV category sales																
Particulars	**Years**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Capital cost for installation	Rs. Crore	3371.9														
Expected energy consumption from EVs	MUs	25,217.5	26,226.2	27,275.2	28,366.3	29,500.9	30,680.9	31,908.2	33,184.5	34,511.9	35,892.4	37,328.1	38,821.2	40,374.0	41,989.0	43,668.6
Operation and Maintenance cost	Rs. Crore	33.7	35.4	37.2	39.0	41.0	43.0	45.2	47.4	49.8	52.3	54.9	57.7	60.6	63.6	66.8
Depreciation	Rs. Crore	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	528.7	528.7
Interest on Term Loan	Rs. Crore	236.0	218.2	200.4	182.6	164.8	147.0	129.2	111.4	93.6	75.8	58.0	40.2	22.4	4.6	-
Return on Equity	Rs. Crore	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8	156.8
Total Fixed Cost	Rs. Crore	604.6	588.5	572.4	556.5	540.6	524.9	509.2	493.7	478.3	462.9	447.8	432.7	417.8	753.7	752.3
Discount Factor	Calculated	1.00000	0.90909	0.82645	0.75131	0.68301	0.62092	0.56447	0.51316	0.46651	0.42410	0.38554	0.35049	0.31863	0.28966	0.26333
Total cost	Rs/kWh	0.2397	0.2244	0.2099	0.1962	0.1833	0.1711	0.1596	0.1488	0.1386	0.1290	0.1200	0.1115	0.1035	0.1795	0.1723
Levelized Tariff Impact	Rs/kWh	**₹0.17897**														
Interest on Loan																
Opening Balance	Rs. Crore	2360.3	2182.3	2004.3	1826.2	1648.2	1470.1	1292.1	1114.1	936.0	758.0	580.0	401.9	223.9	45.9	0
Constant Repayment	Rs. Crore	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	45.9	0
Closing Balance	Rs. Crore	2182.3	2004.3	1826.2	1648.2	1470.1	1292.1	1114.1	936.0	758.0	580.0	401.9	223.9	45.9	0.0	0
Interest on Loan	Rs. Crore	236.0	218.2	200.4	182.6	164.8	147.0	129.2	111.4	93.6	75.8	58.0	40.2	22.4	4.6	0
Depreciation																
Opening Balance	Rs. Crore	3371.9	3193.9	3015.8	2837.8	2659.8	2481.7	2303.7	2125.6	1947.6	1769.6	1591.5	1413.5	1235.5	1057.4	528.7
Annual Depreciation	Rs. Crore	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	178.0	528.7	528.7
Closing Balance	Rs. Crore	3193.9	3015.8	2837.8	2659.8	2481.7	2303.7	2125.6	1947.6	1769.6	1591.5	1413.5	1235.5	1057.4	528.7	0.0

Example: MSEDCL

S.No	Detail	NEMMP high growth (all consumers)	NEMMP high growth (only EV users)	NEMMP+ high growth (all consumers)	NEMMP+ high growth (only EV users)
1	**Tariff impact as incremental wheeling charges, INR/kWh**	0.001	0.281	0.004	0.191
	Base tariff options				
2A	**ACoS, INR/kWh**	6.74	6.74	6.74	6.74
2Ba	**Commercial consumer base (HT) energy charges, INR/kWh**	11.4	11.4	11.4	11.4
2Bb	**Commercial consumer base (HT) energy charges, INR/kWh**	0.59	0.59	0.59	0.59
2C	**Average Power Procurement Cost, INR/kWh**	4.01	4.01	4.01	4.01
2D	**Highest marginal cost from the merit order stock, INR/kWh**	4.86	4.86	4.86	4.86
3	**Differential between ACoS and APPC, , INR/kWh**	2.73	2.73	2.73	2.73
	Total charges including incremental wheeling charges, INR/kWh				
4	**Total charges at ACoS, INR/kWh (=1+2A)**	6.74	7.02	6.74	6.93
5	**Total charges at Commercial (HT), INR/kWh (=1+2Ba+2Bb)**	11.99	12.27	11.99	12.18
6	**Total charges at APPC, INR/kWh (=1+2A+3)**	6.74	7.02	6.74	6.93
7	**Total charges at highest marginal cost, INR/kWh (=1+2A+3)**	7.59	7.87	7.59	7.78

ToD incentives corresponding to usage of stranded assets					
		FY 2016-17	**FY 2017-18**	**FY 2018-19**	**FY 2019-20**
Back Down capacity	MW	6,379	8,961	7,257	6463
Capacity Charges related to Back down	INR Crore	3,988	4,357	4,027	3,710
Capacity charges per MW	INR Crore/MW	0.625	0.486	0.555	0.574

Capacity utilization factor	100%
Annual hours	3650

Maximum level of TOD incentives			
		NEMMP	**NEMMP+**
Electricty consumed by EVs in MSEDCL area	MUs	532	2521.75
Maximum stranded capacity that can be utilised	MW	145.80	690.89
Total incentive to be offered to the Evs	INR, Crore	91.15	431.93
Incentive	INR Crore/MW	1.71	1.71

Note:

1. Based on assumption that the investment and infrastructure in MSEDCL would 10% of the national level.

Annexure VII: Broad principles for special EV Tariffs

1. Scope of these principles

1.1. The Regulatory Commission shall determine the Tariff, and Fees and Charges for public charging of Electric Vehicles (EVs), including terms and conditions thereof, in accordance with these principles, including the following: -

i. Supply of electricity by a Distribution Licensee or Franchisee of the Distribution Licensee to owners of electric vehicles

ii. Bulk procurement of electricty by the Franchisee from the Distribution Licensee

iii. Rates and charges for recovering the investment made in establishing the required infrastructure for public charging of electric vehicles

2. Components of tariff for Distribution of electricty to EV owners

2.1. It is recommended that a separate category of consumers is created for public charging of Electric Vehicles by the respective Regulatory Commission.

2.2. The tariff for EV category should be close to Average Cost of Supply for a Distribution Licensee computed as the ratio of the Aggregate Revenue Requirement of the Distribution Licensee for the Year, determined in accordance with the applicable MYT Regulations, to the total sales of the Distribution Licensee for the respective Year.

2.3. An incremental charge providing for the recovery of the investment in the required public EV charging infrastructure should be added to the ACoS. Tariff for EV category thus, should be comprising the following components:

(a) Average cost of supply (ACoS) of the Distribution Licensee

(b) the incremental tariff over and above the ACoS and comprising of following for the recovery of the investment made in public EV charging infrastructure

i. Capital expenditure

ii. Operation and maintenance expenses;

iii. Depreciation;

iv. Interest on loan capital;

v. Interest on working capital;

vi. Return on equity capital;

vii. Provision for bad and doubtful debts; and

viii. Income tax

2.4. The Cross susbsidy surcharge shall be waived off for EV category if the power is procured through open acess

2.5. The Tariff for retail supply may comprise of any combination of fixed/demand charges and energy charges, for recovery from the consumers, as stipulated by the Commission. Option of utilizing pre-paid meters can be explored as it will provide better visibility and control to the end user for charging EVs.

2.6. The Distribution Licensee may offer a rebate to the consumers on the Tariff and charges determined by the Commission, however, the impact of such rebates on the Distribution Licensee shall be borne entirely by the Distribution Licensee and the impact of such rebate shall not be passed on to the other consumers. Such rebates should not be offered selectively to any consumer/s, but to the entire consumer category/sub-category/consumption slab in a non-discriminatory manner.

3. Capital Investment Plan

3.1. The Distribution Licensee shall submit a detailed Capital Investment Plan, financing plan and physical targets for each year for strengthening and augmentation of its distribution network for serving EV owners, meeting the requirement of load growth etc.

3.2. The Distribution Licensee shall submit separate details of Capital Investment being undertaken in each Distribution Franchisee area within its License area.

4. Operation and Maintenance Expenses

4.1. The Distribution Licensees shall be permitted to recover Operation and Maintenance expenses as per the norms specified by the respective Commissions in accordance with the Multi-Year Tariff Regulations.

5. Financial Principles for Computation of Incremental Charges

As described in clause 2.3 the incremental tariff over and above the ACoS for EV category should comprise the following for the investment made in public EV charging infrastructure.

5.1. Capital Expenditure and Cost

5.1.1. Capital cost for a capital investment Project shall include:

a. the expenditure incurred or projected to be incurred, including interest during construction and financing charges

b. capitalized initial spares in accordance with MYT Regulations
c. expenses incurred by the Licensee on obtaining right of way
d. additional capital expenditure

5.1.2. The capital cost of the assets forming part of the Project but not put to use or not in use, shall be excluded from the capital cost.

5.1.3. The approval and provision of any additional capital expenditure may be done by the respective Commission in accordance with the MYT regulations.

5.2. Debt Equity Ratio

5.2.1. Debt-equity ratio as on the date of commercial operation shall be 70:30 of the amount of capital cost approved by the respective Commission.

5.3. Depreciation

5.3.1. The depreciation on the value of fixed assets used in their respective Businesses, shall be computed in the following manner:

a. The approved original cost of the fixed assets shall be the value base for calculation of depreciation. It shall be allowed on the entire capitalised amount of the new assets after reducing the approved original cost of the retired or replaced or de-capitalised assets.
b. Depreciation shall be computed annually based on the straight-line method at the applicable rates specified by the respective Commission.
c. Once the individual asset is depreciated to the extent of seventy (70) percent, remaining depreciable value as on 31st March of the year closing shall be spread over the balance useful life of the asset.
d. The salvage value of the asset shall be considered at 10 per cent of the allowable capital cost and depreciation shall be allowed up to a maximum of 90 per cent of the allowable capital cost of the asset.

5.3.2. Land other than the land held under lease shall not be a depreciable asset and its cost shall be excluded from the capital cost while computing depreciable value of the assets.

5.4. Return on Equity

5.4.1. Return on equity shall be allowed on the equity capital at the rate as determined by the respective Commission in accordance with the MYT Regulations.

5.5. Interest on loan

5.5.1. The loans arrived on the assets put to use shall be considered as gross normative loan for calculation of interest on loan.

5.5.2. The repayment during each year shall be deemed to be equal to the depreciation allowed for that year.

5.5.3. Notwithstanding any moratorium period availed, the repayment of loan shall be considered from the first year of commercial operation and shall be equal to the annual depreciation allowed.

5.5.4. The rate of interest shall be determined by the respective Commission.

5.6. Interest on Working Capital

5.6.1. The working capital requirement shall cover:

a. Operation and maintenance expenses for one month;

b. Maintenance spares at one per cent of the historical cost; and

c. One and half month’s equivalent of the expected revenue; minus

d. Amount held as security deposits in cash from consumers; and

e. One-month equivalent of cost of power purchased, based on the annual power procurement plan

5.6.2. Rate of interest on working capital shall be determined by the respective Commission in accordance with MYT Regulations.

5.7. Income Tax

5.7.1. The Income Tax payable shall be determined and approved by the respective Commission.-