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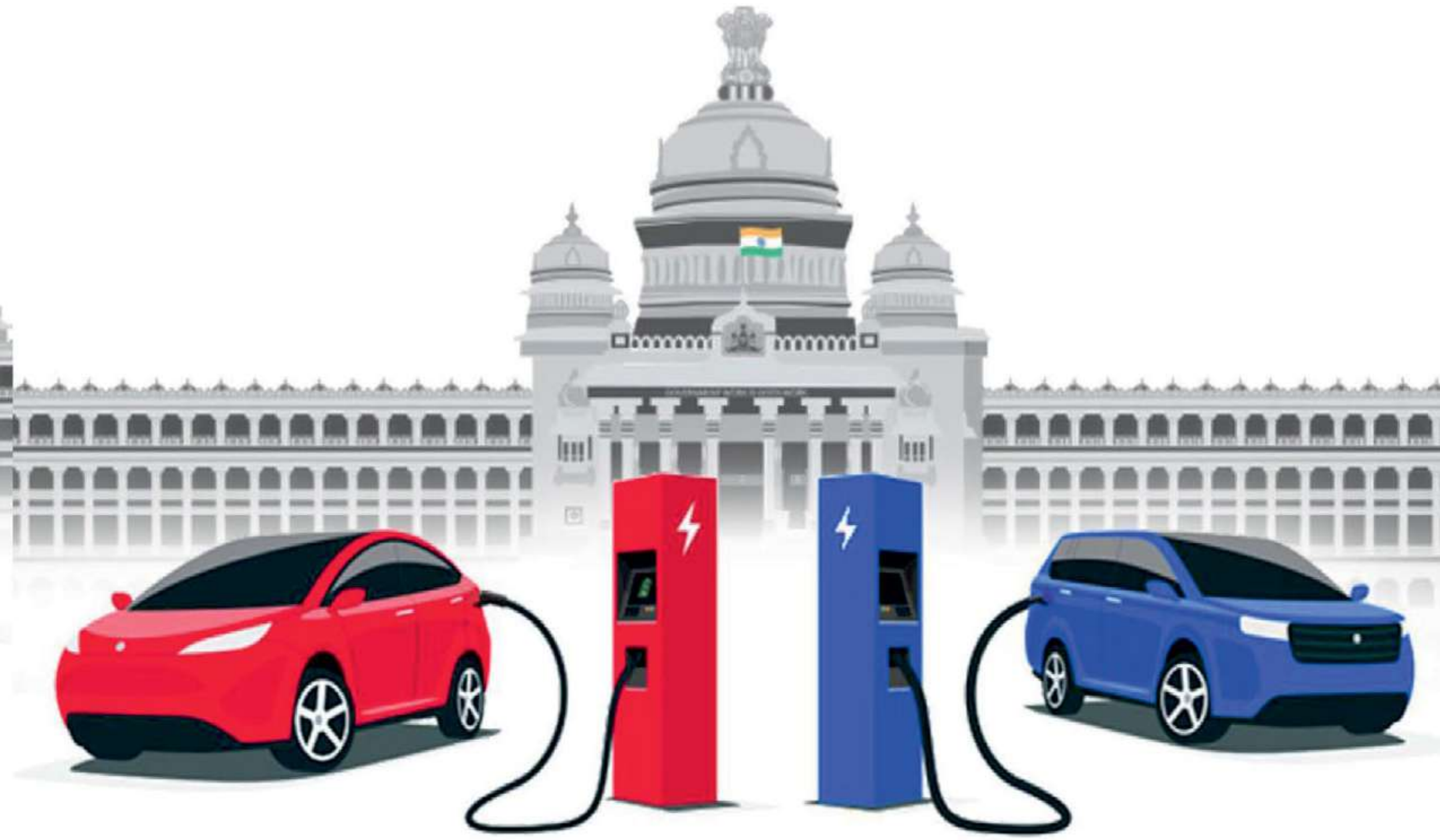
SHAKTI SUSTAINABLE ENERGY FOUNDATION

ISGF India Smart Grid Forum

Study of
ELECTRIC VEHICLE CHARGING INFRASTRUCTURE PLANNING AND ROLLOUT FOR BENGALURU CITY, KARNATAKA

September 2021



Submitted to

BESCOM

Submitted by

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P. Rajendra Cholan, IAS
Managing Director

Message from MD BESCOM

I am pleased to note that India Smart Grid Forum (ISGF) supported by Shakti Sustainable Energy Foundation has completed a detailed study on Electric Vehicle Charging Infrastructure Planning and Rollout for Bangalore City, Karnataka.

BESCOM is one amongst the progressive electricity distribution companies in India and always has been a front-runner in implementing new technologies. BESCOM is identified as the 'State Nodal Agency' for setting up EV charging infrastructure across the state to support Government of Karnataka's initiatives of making Bengaluru the EV capital of India.

BESCOM has already installed 136 charging points in Bengaluru City and this is a first of its kind study that brings out the technical issues related to the impact of AC-DC conversion for EV charging on the grid and its mitigation measures. The study results give very valuable insight for all electric utilities on planning and allocation of new connections to EV charging stations.

I congratulate ISGF for this work and wish them success in their future endeavors.

P Rajendra Cholan, IAS
MD, BESCOM

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To,
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Dr. Anshu Bhardwaj
Chief Exective OfficerShakti Sustainable Energy Foundation

The coming decade will witness an energy shift—from fossil fuels to electricity using renewable sources. This is expected to drive electrification across sectors, including urban transportation.

Currently, the adoption of electric vehicles (EVs) in the country is miniscule. Electric vehicles are cheaper to use on a per km life cycle cost basis. However, the initial costs of purchase are high. The subsidies offered by the Central Government's Faster Adoption and Manufacturing of Electric Vehicles in India Phase II (FAME) and by the State governments (purchase and scrappage incentives) do incentivise EV purchase.

However, EVs carry range anxiety (km run per charge). Under the FAME scheme, about 430 charging stations have been installed across India, with another 2,900 sanctioned. An emerging challenge is that the current distribution end power networks are not geared up to meet EV power demand. If the shift to EV's is to manifest, then it is important to strengthening the capacity of the distribution grid to accommodate the growing load.

Shakti Sustainable Energy Foundation is engaging with Distribution Companies and policymakers at the national and state level to create supportive policies mandates towards accelerating electric mobility in India.

A key interest area is to develop interventions and business models for Discoms to adopt and promote EV charging stations within their jurisdictions. We are pleased to know that the support offered to Bangalore Electricity Supply Company Limited (BESCOM) via the India Smart Grid Forum (ISGF) under a Shakti funded initiative has resulted in the development of such a plan of action to deploy EV charging infrastructure and associated grid upgrades.

We hope this work sets a precedence for distribution utilities across the country to plan for the growing EV load.

Dr. Anshu Bhardwaj
Chief Executive Officer

Preface

Reji Kumar Pillai
President, India Smart Grid Forum
Chairman, Global Smart Energy Federation

Government of India targets to achieve penetration of 30% electric vehicles (EV) by 2030 with multiple initiatives to promote manufacturing and adoption of EVs. With battery costs declining at a faster rate making EVs competitive with ICE vehicles while petrol and diesel prices constantly on the rise, this target looks achievable. Other incentives such as subsidies, waiver of road tax and registration fee are also accelerating the EV adoption in the country. The availability of adequate charging infrastructure is one of the key requirements to support the adoption of EVs.

Electricity distribution companies (DISCOMs) are a major stakeholder in the e-mobility domain as large number of charging stations would require significant grid upgrades. The process of AC to DC conversion for charging the EV batteries injects harmonics on to the electric grid. Unplanned and uncontrolled charging could lead to failure of transformers and cables. In order to understand the extent of these technical issues, ISGF undertook the detailed modelling studies on the network of Bengaluru Electricity Supply Company Ltd (BESCOM) where 136 charging stations are already in operation. ISGF has done a detailed load flow study and analysis of 12 number of 11 kV feeders in Bengaluru on which EV charging stations are connected. Besides the existing scenario in 2020, we have assumed different scenarios of load growth, increase in EV charging load and solar rooftop penetration on these feeders in the years 2022 and 2025 to evaluate the grid upgrade requirements. In most cases, the distribution transformers and cables need upgrade as well as installation of harmonic filters.

This is a first of its kind detailed study undertaken anywhere and this gives insights to DISCOMs across the country to develop a holistic plan for EV charging station rollouts. ISGF is also advocating for vehicle-to-grid (V2G) technologies to be made mandatory for AC charging points where EVs will be connected to the grid for longer hours. With V2G functionality, EVs could provide voltage and frequency support to the grid which will be a win-win situation for both EV owners as well as distribution grid operators; and will also help in solar rooftop integration with the grid.

Reji Kumar Pillai

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We would like to thank Trident Tech Labs Pvt Ltd., for helping us in the load flow studies of the distribution network feeders.

We would like to thank Bhushan Khade, Alekhya Vaddiraj, Bindeshwary Rai for reviewing the report. We also like to extend our sincere gratitude to all the stakeholders for their cooperation during the course of this study.

Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following areas: clean power, energy efficiency, sustainable urban transport, climate change mitigation, and clean energy finance.

India Smart Grid Forum is a Public-Private Partnership initiative of Ministry of Power (MoP), Government of India for accelerated development of smart grid technologies in the Indian power sector. The mandate of ISGF is to advise Government on policies and programs for the promotion of Smart Grids in India, work with national and international agencies in standards development, and help utilities, regulators and the Industry in technology selection, training and capacity building.

Disclaimer:

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Abbreviations

BBMP	Bruhat Bengaluru Mahanagara Palike
BESCOM	Bangalore Electricity Supply Company Limited
BIS	Bureau of Indian Standards
CCS	Combined Charging System
CNG	Compressed Natural Gas
CPO	Charge Point Operator
DER	Distributed Energy Resource
DHI	Department of Heavy Industries
ESS	Energy Storage System
EVSE	Electric Vehicle Supply Equipment
FAME	Faster Adoption and Manufacturing of Hybrid and Electric Vehicles
GoI	Government of India
GoK	Government of Karnataka
IRENA	International Renewable Energy Agency
ISGF	India Smart Grid Forum
LADWP	Los Angeles Department of Water and Power
LNG	Liquefied Natural Gas
MESD	Mobile Energy Storage Device
MHIPE	Ministry of Heavy Industries and Public Enterprise
MIIT	Ministry of Industry and Information Technology
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MoRTH	Ministry of Road Transport and Highways

NEMMP	National Electric Mobility Mission Plan
NEV	New Electric Vehicle
OCPI	Open Charge Point Interface
OCPP	Open Charge Point Protocol
OSCP	Open Smart Charging Protocol
OpenADR	Open Automated Demand Response
PCS	Public Charging Station
PG&E	Pacific Gas & Electric
PHEV	Plug-in Hybrid Electric Vehicle
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SMUD	Sacramento Municipal Utility District
SRTPV	Solar Rooftop Photovoltaic
TEPCO	Tokyo Electric Power Company
ToU	Time of Use
V2G	Vehicle to Grid
V2X	Vehicle to Everything
VESS	Virtual Energy Storage System
VGF	Viability Gap Funding
VPP	Virtual Power Plant
VRE	Variable Renewable Energy
WBTC	West Bengal Transport Corporation
ZEV	Zero Emission Vehicle

Executive Summary

India has launched several schemes and initiatives to stimulate and expedite the adoption of Electric Vehicles (EVs) in the country, starting with the National Electric Mobility Mission Plan (NEMMP) 2020 issued in 2013. As a part of NEMMP, the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme was introduced in 2015, to promote EVs and create an EV manufacturing ecosystem. Under the first phase of FAME, the Department of Heavy Industries (DHI) allocated a grant for 390 electric buses, 370 taxis and 720 three-wheelers to 10 cities with a total investment of INR 5.37 billion. The FAME II, an extension of the FAME scheme, launched in 2019 (till 2022) with a total outlay of INR 100 billion to support the development of both EV and EV charging infrastructure. The FAME II provides support in terms of incentives to EV buyers and state transport undertakings and power utilities to acquire electric buses and set up public charging stations. Several ministries and departments (the DHI, Ministry of Road Transport and Highways (MoRTH), Ministry of Finance (MoF), Ministry of Housing and Urban Affairs (MoHUA), Ministry of Power (MoP), Ministry of New and Renewable Energy (MNRE) and NITI Aayog) have come up with various policies, regulations, guidelines and roadmaps to accelerate the growth of electric mobility in the country. Eighteen state governments have released their electric vehicle policies. Twenty-one states and one union territory have also introduced separate electricity tariff for EV charging.

The government of Karnataka (GoK) had issued the Karnataka Electric Vehicle and Energy Storage Policy in 2017 (first state in the country), with the vision of making Karnataka a preferred destination for electric mobility ecosystem through special initiatives for EV manufacturing, support for charging infrastructure, support for research and development, skill development, incentives and concessions. The policy aims to develop charging infrastructure as a commercially viable business venture that would attracts private investment—incentives in subsidies offered for setting up the first 100 charging stations. In August 2019, the DHI invited expressions of interest (EoI) for the deployment of EV charging infrastructure under FAME II from urban local bodies (ULBs)/ municipal corporations, PSUs (central/state) and public/private entities. As per the EoI results notified in January 2020, the DHI has sanctioned 2,636 charging stations in 62 cities across 24 states/union territories. Under this scheme, Karnataka state has received 172 charging stations.

To give a further push to clean mobility in the road transport sector, Karnataka Government announced establishing an EV and energy storage manufacturing cluster in the state under FY 2020-21 state budget with an investment of INR 1.0 billion (~USD13.56 million). Also, Karnataka Government announced to set up 1,000 EV charging stations (EVCS) under the public-private partnership (PPP) model in the state. The proposed plan will be under the fifth stage of the Karnataka Industrial Area Development Board (KIADB) industrial area in Harohalli in Ramanagara districts. Also, the state government is providing a grant of INR 1 billion for 500 electric buses to the fleet of the public transport corporations[1] in the state. Furthermore, to improve the last mile connectivity in public transport in Bengaluru City, the State Government proposed implementing the "Electric Bike Taxi" project. Furthermore, the Karnataka Power Corporation Limited (KPCL) has also proposed establishing a new waste to energy power generation plant of 11.5 MW capacity in Bidadi in Ramanagara district at an estimated cost of INR 2.1 billion (USD 28.49 million). Also, the Karnataka Government in June 2020 decided to entirely waive off stamp duty and registration charges for the manufacture and sale of EVs in the state.

Bangalore Electricity Supply Company Ltd (BESCOM) is the State Nodal Agency for setting up EV charging infrastructure in Karnataka. BESCOM distributes electricity to over 12 million customers in Bengaluru City and adjacent districts of Kolar, Tumakur, Ramanagara, Chikkaballapur, Chitradurga and Davanagere covering an area of 41,092 sq km. BESCOM is owned by the GoK and is one of the advanced electricity distribution companies (DISCOMs) in India and has always been a front runner in implementing new technologies.

BESCOM has developed a plan for installing 678 charging stations across Karnataka, out of which, 162 have been proposed in Bengaluru City. As part of this, BESCOM has already installed 136 charging stations at 74 locations (32 DC fast-chargers at 15 locations and 104 AC chargers at 74 locations) in Bengaluru City. In the process of this pilot implementation, BESCOM realized the need for assessing the capacity of the distribution grid to accommodate the EV load. In many locations, the grid may require an upgrade for accommodating the EV load. This upgrade requires detailed modelling studies. BESCOM availed the professional services of India Smart Grid Forum (ISGF) to assist them in preparing the detailed plan for the deployment of EV charging infrastructure and associated grid upgrades wherever required. ISGF undertook this study to prepare the plan for EV charging infrastructure for Bengaluru City. The primary outcomes of the study are as follows:

- Detailed modelling studies are conducted on 12 of 11 kV feeders in Bengaluru City with different scenarios of EV load and solar rooftop photovoltaic (SRTPV) penetration in the years 2020, 2022 and 2025
- Recommendations for network upgradations to accommodate EV loads in different scenarios
- Identification of ideal locations in Bengaluru

1 Mercomindia report: https://bit.ly/38Lcs14

City for establishing EV Charging Stations (EVCS)

- Evaluation of the business models and recommendations

Recommendations on the infrastructure requirements (Software/Hardware) for managing the EV charging stations.

Layout of this Report

This study covered twelve of the 11 kV feeders of BESCOM in Bengaluru City, and the report contains 11 chapters and annexures. The report includes the modelling study results of 12 feeders and recommendations for grid upgrades. Annexures include the number of buses allotted under FAME II, EV policies in various states in India, DC fast charger specifications, and the detailed analysis of 12 of the 11 kV feeders for various scenarios of EV load and SRTPV penetrations in the years 2020, 2021, 2022 and 2025 and ISGF recommendations to bus charging in depots and locations of EV charging stations across Bengaluru City.

Chapter 1 lays out the foundation of the study and provides context, current scenario of the transport and electricity sector in the City of Bengaluru. It also elaborates the study objectives, scope, and methodology for the study. **Chapter 2** gives the global electric mobility scenario in terms of adoption, emerging technologies, and policies in the largest EV markets across the globe. The global EV fleet expanded significantly over the last decade, underpinned by supportive policies, a significant reduction in battery prices, and technology advancements. **Chapter 3** describes the existing EV scenario in India, the world's largest manufacturer of 2-wheelers and 3-wheelers. About 30 million vehicles across various segments were produced in FY 2019. In addition to the central government, 18 state governments such as Delhi, Karnataka, Uttar Pradesh, Andhra Pradesh, Kerala, Telangana, Tamil Nadu, Bihar, Uttarakhand, West Bengal, Gujarat, Maharashtra, etc. have issued state-specific EV Policies focusing on the manufacture and deployment of EVs and charging facilities in the state. **Chapter 4** covers the diverse automotive scenario in the state of Karnataka. With the mandate to make Bengaluru the EV capital of India, Karnataka was the first state to introduce an electric vehicle policy in September 2017. BESCOM has set up EVCS at 74 locations to achieve the 2017 Karnataka electric vehicle and energy storage policy goals and has installed 136 EV chargers.

Chapter 5 presents the potential technical issues and grid impact challenges that need to be addressed for enabling EV integration in the distribution grid in BESCOM feeders where EVCS are connected. Study findings from 12 feeders and the recommendations for grid upgrades to accommodate EV loads are presented in this chapter. **Chapter 6** gives the list of about 300 public charging locations identified across Bengaluru City. **Chapter 7** evaluates the current business model of BESCOM for operating the 74 EVCS and compares it with other charging station operators in India and gives recommendations for attracting private investment in the setting-up and operation of EVCS. The chapter also covers Vehicle–Grid Integration (VGI) concepts, case studies and options for wide-scale deployment of a system that ensures SRTPV and EV charging and battery storage during non-peak periods and feedback of power to the grid when required.

Chapter 8 compares the electricity tariff for EV charging across India, a vital fiscal and regulatory instrument for EV adoption. The tariff must be structured to enable the utility to recover costs while making EV charging is cost-effective for the EV owner and allowing charging services to be commercially viable. It also discusses the key factors for setting the electricity tariff for EV charging. **Chapter 9** examines the feasibility of utilisation of existing fuel refilling stations for setting up EV charging stations. **Chapter 10** describes the EV charging software requirements and various communication protocols, which provides rules and regulations to facilitate the communication and data exchange between two or more entities to ensure successful charging demand management and electricity grid integration of EVs. Finally, **Chapter 11** recommends the way forward for BESCOM, taking into account the various technical requirements of charging stations and the support required for EV charging infrastructure deployment through direct procurement, providing rebates or other incentives to encourage customers and third-party investments, and deployment of systems with open standards and protocols to promote interoperability and adoption.

Summary of the Study Results of the 12 Feeders

List of the 12 feeders and the scenarios considered for modelling studies are given in the Table below:

Table ES-1: Summary of load flow study conducted and scenarios simulated

List and Characteristics of 12 Feeders Studied							2020			2022			2025		
Sl No	Substation Name	Feeder Name	Line Length (km)			Number of DTs	Peak Load (MW)	EVSE Load (kW)	SRT-PV Load (kW)	Peak Load (MW)	EVSE Load (kW)	SRT-PV Load (kW)	Peak Load (MW)	EVSE Load (kW)	SRT-PV Load (kW)
			Over-head	Under-ground	Total Length										
1	66/11 kV Arehally	F03 Ittamadu	10.1	18.5	28.6	22	2.73	44	0	3.067	144	100	3.65	344	500
2	66/11 kV HAL	F07 HAL	4.3	23.8	28.1	25	1.88	44	0	2.11	144	100	2.52	344	500
3	66/11 kV Hoody	F08 ITI AUX	13.99	50.5	64.49	61	5.29	44	0	5.95	144	100	7.08	344	500
4	66/11 kV Brindavana	F19 KIADB	0.4	2.09	2.49	9	0.55	44	0	0.62	144	100	0.74	344	500
5	66/11 kV Vidhana Soudha	F01 C-Station	1.716	15.99	17.706	11	4.99	44	0	5.61	144	100	668	344	500
6	66/11 kV Amarjyothi	F04 Cross-RMU	1.8	16.5	18.3	12	2.72	44	0	3.06	144	100	3.64	344	500
7	66/11 kV Banaswadi	F07 Subbaihanpalya	35.5	57.7	93.2	140	4.32	44	0	4.86	144	100	5.78	344	500
8	66/11 kV Banashankari	F25 BSK	16.26	34.2	50.46	55	3.69	44	0	4.15	144	100	4.94	344	500
9	220/11 kV HSR Layout	F03 HSR	15.6	18.7	34.3	64	3.11	44	0	3.50	144	100	4.16	344	500
10	66/11 kV KHB	F08 Byatha	10.4	9.92	20.32	37	5.56	44	0	6.25	144	100	7.44	344	500
11	66/11 kV Mathikere	F07 MTK	20	44.5	64.5	59	3.81	44	0	4.28	144	100	5.10	344	500
12	66/11 kV St. Johnswood	F01 SJW	9.35	18.3	27.65	66	5.96	44	0	6.70	144	100	7.97	344	500

The mitigation measures recommended for the sample feeder (11 kV Ittamadu feeder) are summarized in the Table below.

Table ES-2: Mitigation measures recommended for 11 kV F07 Ittamadu feeder

Year	EV and SRTPV	Fault Scenario				Mitigation Measures Recommended		
	Level of EV and SRTPV	Under Voltage (Volt) Elements	Overload (Locations)	Current Harmonics /Voltage Harmonic	Cable Fault (Yes/ No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2020	44 kW EV load	53	727	Current harmonics	Yes	1. TC17 GANAPATHI TEMPLE: New DT of 1000 kVA 2. TC130 NEAR ANJANEYA TEMPLE: New DT of 100 kVA 3. TC18 ITTAMADU: New DT of 150 kVA 4. TC22 NEAR OMSHAKTI TEMPLE: New DT of 50 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated 20 kVAR; along with a C-type Filter rated 100 kVAR tuned at 3rd order harmonic frequency at EVCS-1.	Yes, with higher withstand capacity.
2022	144 kW EV load and 100 kW SRTPV	58	793	Current harmonics	Yes	1. TC17 GANAPATHI TEMPLE: New DT of 1200 kVA 2. TC130 NEAR ANJANEYA TEMPLE: New DT of 100 kVA 3. TC18 ITTAMADU: New DT of 150 kVA 4. TC22 NEAR OMSHAKTI TEMPLE: New DT of 63 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated 30 kVAR for EVCS-1&2; along with a C-type filter rated 100 kVAR for EVCS-1 and 150 kVAR for EVCS-2 tuned at 3rd order harmonic frequency.	Yes, with higher withstand capacity.
2025	344 kW EV load and 500 kW SRTPV	64	927	Current harmonics	Yes	1. TC17 GANAPATHI TEMPLE: New DT of 1500 kVA 2. TC130 NEAR ANJANEYA TEMPLE: New DT of 100 kVA 3. TC18 ITTAMADU: New DT of 150 kVA 4. TC22 NEAR OMSHAKTI TEMPLE: New DT of 100 kVA 5. TC21 ANJANEYA: New DT of 50 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated 30 kVAR for EVCS-1&2; along with a C-type filter rated 100 kVAR for EVCS-1; and 50 kVAR for EVCS-2 tuned at 3rd order harmonic frequency. For EVCS-3, double tuned filter of 50 kVAR and 100 kVAR C-type filter.	Yes, with higher withstand capacity.

The details of the load flow study, analysis and mitigation measures of the 11kV Ittamadu Feeder are covered in this volume. The same for rest of the 11 feeders are given in the Annexure as a separate volume.

1 INTRODUCTION

1.1 Background

India's decarbonization policies to address greenhouse gas (GHG) emissions and to drive new economic opportunities while enhancing citizens' quality of life have made the transport sector one of the Government's main focus areas. To address this issue, India has started its journey towards electrification of transportation in 2013 with the launch of National Electric Mobility Mission Plan (NEMMP) 2020 by Government of India (GoI) which envisaged rollout of 6-7 million electric/hybrid vehicles in India by 2020. Several ministries and departments including the Ministry of Road Transport and Highways (MoRTH), Department of Heavy Industries (DHI), Ministry of Finance (MoF), Ministry of Housing and Urban Affairs (MoHUA), Ministry of Power (MoP), Ministry of New and Renewable Energy (MNRE), NITI Aayog etc. have come up with various guidelines and roadmaps to accelerate the growth of electric mobility in the country. As a part of NEMMP, the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) India scheme was introduced in 2015 to promote electric vehicles (EVs) and EV manufacturing ecosystem. Under the first phase of FAME, DHI allocated a grant for 390 electric buses, 370 taxis, and 720 three-wheelers to 10 cities with a total investment of INR 5.37 billion.

Table 1-1: DHI allocated vehicles for 10 Cities under FAME scheme

Sl No	Cities	Electric Buses	e-Taxis	3-Wheelers
1	Kolkata	80	200	--
2	Ahmedabad	40	20	20
3	Bengaluru[2]	40	100	500
4	Jaipur	40	--	--
5	Mumbai	40	--	--
6	Lucknow	40	--	--
7	Hyderabad	40	--	--
8	Indore	40	50	200
9	Jammu	15	--	--
10	Guwahati	15	--	--
Total		390	370	720

Source: Department of Heavy Industries

The FAME scheme was extended in 2019 as FAME II for the next three years with a total outlay of INR 100 billion. This extension supports the development of both EV and EV charging infrastructure by providing support in terms of incentives to EV buyers, state transport undertakings, and power utilities.

86 percent of FAME II funds has been allocated for demand side incentives for 7,000 electric buses, 500,000 electric three-wheelers, 55,000 electric four-wheelers and 1 million electric two-wheelers.

According to DHI, about 2,85,000 electric and hybrid vehicles buyers benefitted from the subsidies provided under the FAME I. About 26,967 electric vehicles (including 1,284 electric four-wheelers, 6,221 electric three-wheelers, and 19,463 electric two-wheelers) are sold under the FAME II scheme till June 2020. In addition to electric two, three, and four-wheelers, DHI also allocated 5,595 buses[3] to 64 cities for intra-city and intercity operations under the FAME II. Metropolitan cities like Delhi, Mumbai, Hyderabad, Bengaluru, and Ahmedabad have been allocated 300 buses each. For intercity operations, 400 buses are sanctioned to eight state transport undertakings with 50 buses each and Delhi Metro Rail Corporation has received 100 buses for ensuring last mile connectivity in Delhi/NCR. The list of cities and number of buses allocated under FAME II is given in Annexure - I.

1.1.1 Transport Scenario in Bengaluru City, Karnataka

The State of Karnataka has seen a 33% growth in new vehicle registrations between 2015 and 2019. As of September 2019, vehicle

2 Bengaluru Metropolitan Transport Corporation (BMTC) was allotted 40 electric buses under FAME-I, procurement could not be completed within the specified time limits due to government and management changes.

3 DHI - https://bit.ly/3nLFF0q

registrations in Karnataka stand at 20 million, of which 41.9% of the vehicles are registered in Bengaluru City. The total number of registered vehicles has increased almost three-fold between 2007 and 2019, making Bengaluru a City with the highest annual growth rate (14.9%) for vehicle registrations among all megacities in India. Bengaluru is spatially characterized by a ring-radial system of roads formed by five big axes, which converge towards the city center.

Table 1-2: Important transport statistics of Bengaluru Metropolitan Zone (BMZ)

Road network	13,000 km
Road density	8.2 km/sq.km
Average speed for vehicles	17 km/h
Trip rate	0.9 per capita per day – approximately 9 million trips per day
Traffic index	162%

Source: Bengaluru BBMP Smart City Presentation, NITI Aayog Report on Transforming India's Mobility, Revised Master Plan for Bengaluru - 2031.

Table 1-3: Electric vehicles in Bengaluru City

Vehicle	Total Vehicular Population	EV (as of December 19)	EV (%)
Two-wheeler	57,72,673	7,545	0.13%
Three-wheeler	2,01,017	13,522	6.46%
Four-wheeler	17,13,023	6,050	0.35%
Buses	50988	Nil	0.00%
Total	77,37,701	27,117	0.35%

1.1.2 EV Scenario in Bengaluru

Bengaluru has been one of the leading cities in India to adopt EVs, with efforts made by both private as well as public players to fast track the transition as envisaged in the EV policy of Karnataka. Bengaluru City has a total of 27,117 electric vehicles as of December 2019[4].

1.1.3 Electric Mobility Initiatives by Different Stakeholders in Bengaluru

Several private companies have set up approximately 300 charging stations in various pockets of Bengaluru City. Ather Energy Private Limited, an electric two-wheeler manufacturer, has installed 31 charging points at 24 locations, including malls, gyms, cafes, tech parks, etc., within Bengaluru. These points offered free charging to electric two-wheelers and four-wheelers. The electric cab service operator rydS (owned by Baghirathi) have installed charging stations in Banaswadi, Jigani, Kadubeesanahalli, Electronic City, and Nagawara. Mahindra Electric, Lithium Urban Technologies, and other firms have also deployed charging stations at few technology parks. As already stated, BESCOM has set up 136 EV chargers at 74 locations in Bengaluru City.

1.1.4 Alternative Automotive Fuels Options in India to Reduce Green House Gas Emission

GoI has announced fuel efficiency norms for different categories of vehicles. The efforts to improve the fuel efficiency of all modes of transport will help reduce the new fleet fuel consumption. Alternative fuels such as CNG, LPG, LNG, Hydrogen, and biofuels like ethanol, methanol, bio-diesel[5] are promoted.

Bioethanol

Bioethanol is the most common biofuel produced from biomass containing sugar-based components, like sugar cane, sugar beet, sweet

4 Sustainable Mobility for Bengaluru - https://bit.ly/3bUivCP

5 Society of Indian Automobile Manufacturers - https://bit.ly/3jj61Wb sorghum, etc. Therefore, GoI announced various policies from time to time regarding blending of ethanol with gasoline in various proportions, as given below:

2003

- Govt. mandated 5% ethanol blending in 9 states and 4 Union Territories (UTs)

2009

- Biofuel policy target to achieve 20% blending of ethanol by 2017

2019

- Oil Marketing Companies (OMCs) to sell 10% Ethanol Blended Petrol (EBP) or any percentage as per BIS, from 1st April 2019

Biodiesel

Biodiesel is a methyl or ethyl ester of fatty acids produced from non-edible vegetable oils, acid oil, used cooking oil, or animal fat, and bio-oil. GoI notified the following policies for blending biodiesel:

2005: National Biodiesel Mission (NBM): Biodiesel blend of 20% with conventional diesel by 2017

2009: National Policy on Biofuels - 20% blending of bio-diesel by 2017

Methanol

Methanol (CH3OH) is a clear and colourless alcohol fuel produced from various sources like biomass, natural gas, coal, and cellulose. GoI was planning the usage of methanol for automotive purposes. Therefore, GoI notified the following policies for Methanol:

- NITI Aayog, has advised plans for transition to methanol economy in India
- Union Minister for Transport has announced that India will leapfrog to 'Methanol Economy' to reduce the oil import bills as well as to reduce the emissions

Compressed Natural Gas (CNG)

India has been extensively using CNG across the country for public transportation and has mandated CNG for buses, taxis, and Three-wheelers in many cities.

Liquefied Natural Gas (LNG)

LNG is a low-carbon fuel formed by liquefying methane at a low temperature of around -160ºC. The LNG is the fuel with the least emission of pollutants like SO_2, NO_2, CO_2, etc. The emission factor of LNG is only 56,100 Kg/TJ compared to the emission factor of 74,100 kg/TJ of diesel. Therefore estimation of about 0.7 tons per 1,000 litres of reduction of carbon emission if diesel is replaced with LNG.

1.2 Study Scope and Objectives

1.2.1 Scope of the Study

BESCOM has already installed 136 EV chargers at 74 EV Charging Stations (EVCS) - 32 DC fast-chargers at 15 locations and 104 slow AC chargers at 74 locations in Bengaluru City. In the process of this pilot implementation, BESCOM realized the need for assessing the capacity of the distribution grid to accommodate the EV load. In many locations, the grid may require an upgrade for accommodating the EV load. This upgrade requires detailed modelling studies. Therefore, BESCOM requested the professional services of ISGF to assist them in preparing the detailed plan for the deployment of EV charging infrastructure and associated grid upgrades wherever required. The scope of the study covered:

a. Assist BESCOM in the identification of ideal locations for installing charging stations from the perspectives of both EV driver convenience as well as minimum investment on the distribution grid upgrades to support the EV penetration in the City

- o Total 678 EVCS proposed across Karnataka, out of which BESCOM has installed 136 chargers at 74 locations. Out of the remaining 604 locations that need to be identified, about 80 are within Bruhat Bengaluru Mahanagara Palike (BBMP) limits. In addition, a set of locations has been shortlisted by BESCOM and ISGF jointly for installing EVCSs in phase wise manner
- o Explore the feasibility for utilization of existing fuel refilling stations for installing EV charging stations considering the regulatory, institutional, and technological challenges

b. Types of charging stations - size (voltage and current), and number of charging stations in different phases in the identified locations

c. Load flow studies of selected distribution feeders to estimate the requirements for distribution equipment capacity augmentation

- o Load flow assessment conducted on 12 feeders on which EVCS has been installed
- o Analysis was done for three different types of charging stations with different combinations of chargers as given in Table and Figures below:

Table 1-4: Category of charging stations

Sl No	Category of charging stations	Charger type - Charger connector type
1	Slow	Slow – AC (3.3 kW)
2	Fast	Fast DC - CCS/CHAdeMO (25 kW)
3	Mixed	Mixed (DC 15 kW + AC 3.3 kW)

Source: BESCOM

Figure 1-1: Fast DC - CCS/CHAdeMO charger

Source: BESCOM

Figure 1-2: Slow – AC charger

Figure 1-3: Mixed (AC+ DC) charger

d. Review of specifications prepared by BESCOM for procurement of charging stations

e. Estimate the capital investment for typical charging stations recommended and related grid upgrades in a phased manner over the next five years

f. Recommendations for appropriate tariff for EV charging ensuring cost recovery for capital invested in the charging stations and network augmentation

g. Conduct consultations with various stakeholders - government departments, transport operators (BMTC, private bus operators, taxi fleet operators, Bengaluru Metro, Railways, 3-wheeler operators, goods carriers, etc.), vehicle manufacturers, battery manufacturers, charging station manufacturers, etc. to understand their plans and align BESCOM's plan in line with these stakeholders' requirements, expectations, and expansion plans: However, owing to the pandemic situation consultations with the target stakeholders could not be conducted

h. Detailed study and recommendations for grid upgrades for charging a large number of buses in BMTC depots: BMTC has not finalized any plans for electric bus rollout during this study period. Hence, we have included ISGF's advisory for charging facilities installations in bus depots

i. Recommendation on appropriate software applications for managing the EVCS

j. Assess the feasibility of leveraging EVs to store surplus power generated from renewable resources and feedback to the grid during peak hours

k. Recommendations for sustainable business models for EVCS

1.2.2 Objectives

The objectives of the study are:

- Assessing the capacity of the distribution grid to accommodate the EV load
- Detailed modelling and load flow studies of 12 identified feeders
- Estimation of the grid upgrade requirements for EVCS

1.3 Study Methodology

A well-designed research methodology was adopted for this project as outlined below:

Step 1: Identification of Electric Vehicle Charging Station (EVCS) locations

The project identified ideal locations for EVCS installations based on space availability, user convenience, electricity network access, etc.

Step 2: Study and analysis of electrical networks around the identified EVCS locations

The project performed the AS-IS assessment of the distribution networks around the identified EVCS locations in terms of feeder capacity, distribution transformer (DT) capacity, and other network parameters.

Step 3: Load estimation for EVCS in each identified location in phases (2020 - 2025)

The study forecasted the load demand based on the rate of EV adoption in Bengaluru. Accordingly, it estimated the number of EVCS that need to be installed (in each phase) for 2020 - 2025.

Step 4: Load flow studies on 12 feeders and distribution equipment with different scenarios of EVSE load and Solar Rooftop PV

(SRTPV) addition by 2022 and 2025

The project performed load flow analysis to assess the impact of EVCS load and SRTPV on the feeders and distribution equipment; The study also provided the appropriate grid upgrade requirements depending on the impact assessment.

Step 5: Assessment of infrastructure gaps and grid upgrade requirements

The project performed gap assessment of the distribution infrastructure to identify the grid upgrades for EVCS integration.

Step 6: Implementation strategy and plan

The project developed a phase-wise implementation plan and strategy for the rollout of EVCS detailing regulatory, technical, and institutional steps.

Step 7: Stakeholder consultations

The project team collaborated and consulted various stakeholders such as government departments, transport operators (Taxi fleets operators, 3-wheeler operators, and good carriers etc.), vehicle manufacturers, battery manufacturers, charging station manufacturers etc. Though originally envisaged, this could not be conducted owing to the pandemic situation. However, inputs from key stakeholders were collected through BESCOM.

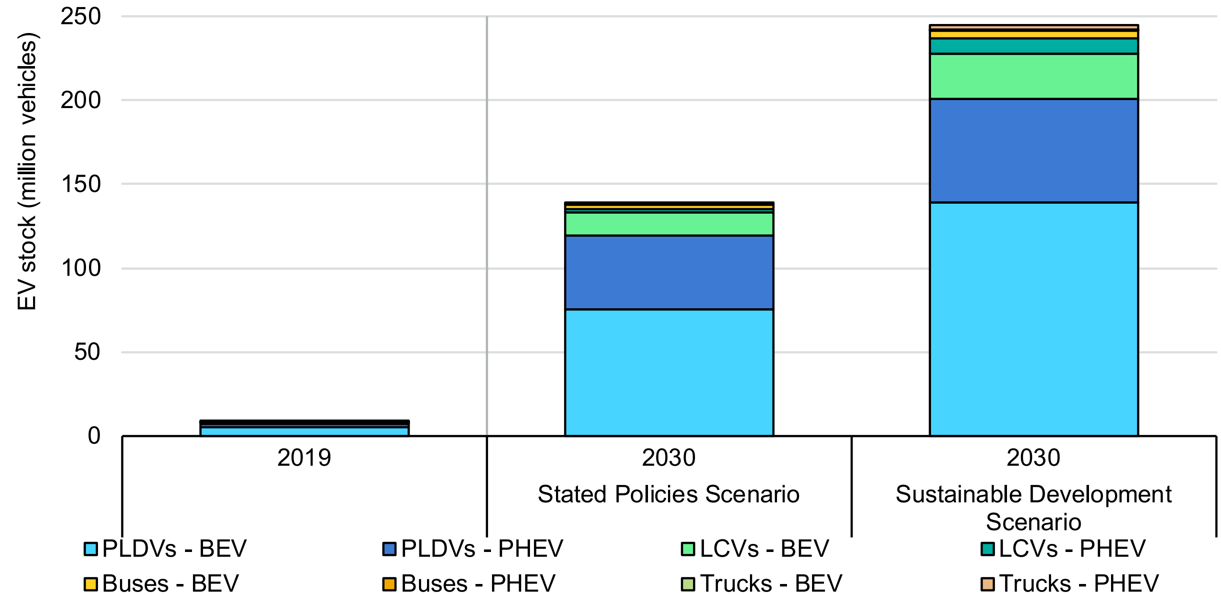
2 STATE OF ELECTRIC MOBILITY AND GLOBAL BEST PRACTICES

This chapter discusses global best practices for the implementation of EVs and proposes suitable practices for India in tune with global technological developments. Global practices and the effect on the grid can help develop Indian policies to speed up the adoption of EVs in India. The Government of India (GoI) expressed its aggressive EV deployment plans through NEMMP and the FAME schemes. Though EV adoption in India is picking up slowly, adopting global best practices and other ecosystem support programs could play a vital role in influencing customers to adopt EVs. In addition, a low tariff for electricity for EV charging and easy access to public charging stations will also play a vital role in the promotion of electric mobility.

Countries across the globe have set their EV adoption targets; many of them are at a nascent stage, whereas others are progressing fast by setting up favourable policy and incentive mechanisms. One of the world's largest EV markets, the USA has ambitious plans at federal as well as at state levels to deploy EVs with better incentives, public funding and loan programs for charging infrastructure deployment, and aggressive R&D investment in key areas of grid modernization, vehicle-grid integration, and interoperability of EVs and chargers. California has set a target for 1.5 million EVs by 2025 and substantial public investment in charging infrastructure by electric utilities.

By 2030, the global EV stock (excluding Two and Three-wheelers) is estimated to be about 140 million in the stated policies scenario, while the more ambitious sustainable development scenario projects about 245 million electric vehicles[6].

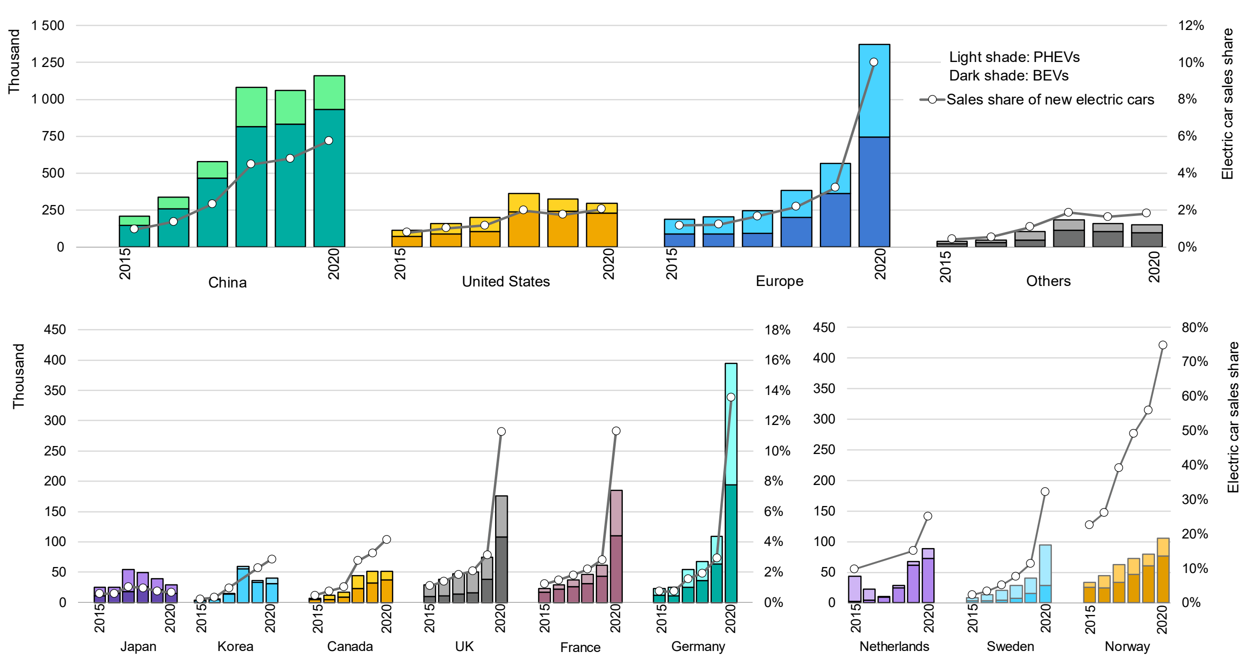
Figure 2-1: Global electric vehicle stock by scenario, year 2019 and 2030



Source: Global EV Outlook 2020 by IEA

After a decade of rapid growth with a 43% increase over the previous year, the global electric car stock hit the 10 million mark in 2020, a 1% stock share of the car market.

Figure 2-2: Passenger electric car sales and market share in selected countries and regions, 2015-2020

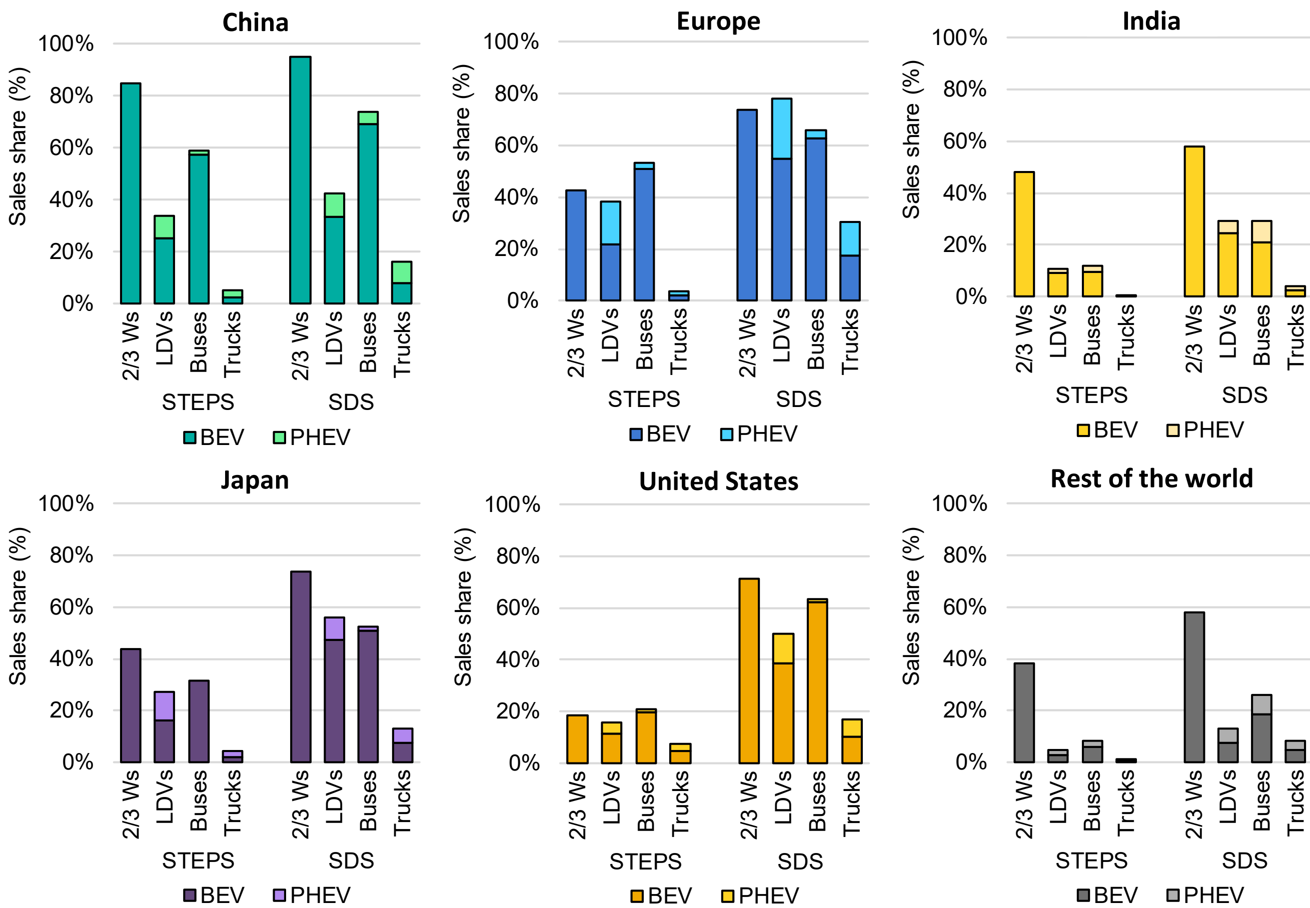


Source: Global EV Outlook 2020 by IEA

[6] *International Energy Agency: https://www.iea.org/reports/global-ev-outlook-2020*

EV deployment proceeds at different speeds across world regions. The below Figure shows the outlook in 2030 for EV uptake by mode and scenario in key regions.

Figure 2-3: EV share of vehicle sales by mode and scenario in selected regions, 2030



Source: Global EV Outlook 2021 by IEA

2.1 Global Electric Vehicle Adoption, Emerging Technologies, and Policies

The Global EV adoption rates are primarily driven by strong state and/or country level policies targeted for the higher market share of 4-wheelers. The below sections describe the key factors which led to market development in the few select countries.

2.1.1 United States of America (USA)

Various states in the USA have adopted different approaches for promoting the installation of EV chargers. California has emerged as one of the largest markets for EVs in the USA. In addition, California has been a trendsetter in the US in environmental reforms. The State Government of California has set a target for 5 million EVs on the road by 2030 and 2,50,000 electric vehicle charging stations by 2025.

Policy roadmap for electric mobility in California:

Table 2-1: Policy roadmap for e-Mobility in California

Sl No	Policy/Initiative	Timeline	Description
1	Electric Vehicle Supply Equipment (EVSE) policies for multi-unit dwellings	2011-2012	Encourages installation or use of EVSE in a homeowner's designated parking space or a common area.
2	Zero-Emission Vehicles (ZEV) promotion plan	2012-2018	• By 2020, the state will have established adequate infrastructure to support one million ZEVs • By 2025, there will be 200 hydrogen fueling stations and 2,50,000 plug-in electric vehicle (PEV) chargers, including 10,000 DC fast chargers, in California • By 2050, GHG emissions from the transportation sector will be 80% less than 1990 levels
3	The California building standards commission: Mandatory EVSE building standards	2013	• Establishes building standards for EVSE installation in parking spaces at multi-family dwellings and non-residential developments
4	Establishment of a zero-emission medium and heavy-duty vehicle program	2014-2020	• US$ 12 million to 20 million in funding annually through 2020 for zero and near-zero emission heavy-duty vehicles, including vocational trucks, short and long-haul trucks, buses, and eligible off-road vehicles and equipment
5	EVSE signage authorization on highways	2017	• EVSE facilities located at roadside businesses are eligible to be included on the state highway exit signboards

Source: Alternative Fuels Data Center

In California, various utilities and private organizations have come up with novel incentives to boost the EV demand.

Utility incentives:

1. **Plug-in EV (PEV) charging rate reduction:** The Los Angeles Department of Water and Power (LADWP) offers a US$0.025 per kilowatt-hour (kWh) discount for electricity used to charge PEVs during off-peak times. Residential customers who install a separate time of use (ToU) meter panel will also receive a US$250 credit. Also, Southern California Edison (SCE) offers a discounted rate to customers for electricity used to charge PEVs.

2. **EVSE and charging incentives:** Sacramento Municipal Utility District (SMUD) offers residential customers a US$ 599 rebate or a free level 2 (240 V) PEV charger.

Role of utilities:

Three investor-owned electric utilities in California, namely, Southern California Edison (SCE), San Diego Gas & Electric (SDG&E),

and Pacific Gas & Electric Company (PG&E), developed proposals for their individual EVSE deployment pilot programs. The pilot programs of the three utilities are summarized below.

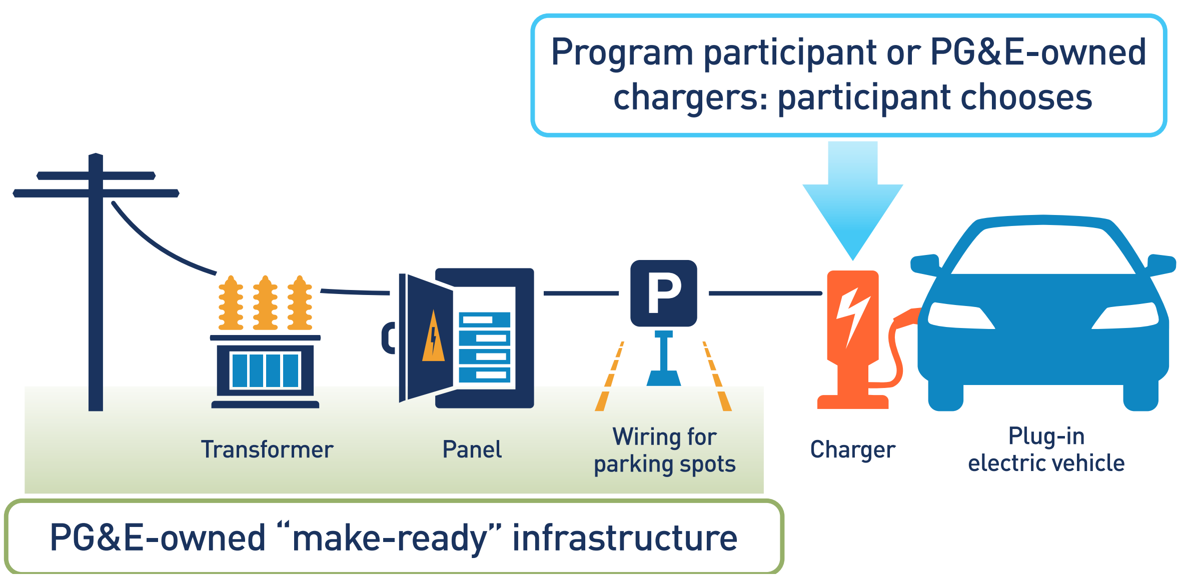
Southern California Edison (SCE) – Charge Ready Program:

Charge Ready is an EV charging infrastructure deployment program run by the SCE to increase 1500 level 1 and level 2 EV chargers in its service territory. The following are the key highlights of the program:

- SCE provides the requisite grid infrastructure at an SCE consumers' premises for installing the EVSE
- The consumer holds the responsibility for procuring, owning, and maintaining the charging infrastructure in accordance with the program rules and regulations
- Any existing non-residential SCE consumer interested in deploying the charging infrastructure at their premises and the sites that offer/consist of long dwell-time parking spaces such as office spaces, fleet parking, cinema halls, stadiums are eligible for the program
- Electric distribution infrastructures, such as transformers, service lines, and meters dedicated to EV charging equipment deployed under the pilot
- Customer-side infrastructure, such as panels, step-down transformers, wiring and conduits, and stub outs, to allow for EVSE installations
- SCE established an advisory board comprised of customers, industry stakeholders, and representatives of disadvantaged communities (DACs)

Pacific Gas and Electric (PG&E) - EV Charge Network Program: PG&E launched the EV Charge Network Program to install 7500 EV chargers at multi-unit dwellings and workplaces throughout its service territory.

Figure 2-4: PG&E owned make-ready infrastructure



Source: PG&E

Key features of the program:

- PG&E will pay for, maintain, and coordinate construction of infrastructure from the transformer to the parking space, often 60-80% of the total project cost
- In addition to the infrastructure, a portion of the charging equipment cost will be paid by PG&E ($575 to $2,300 per port)
- Program participants have the option to own the chargers themselves or have PG&E own them
- Program participants can bill drivers or offer to charge for free
- The program requires a minimum of 10 EV parking spaces per location

San Diego Gas & Electric (SDG&E) - Power Your Drive (Electric Vehicle-Grid Integration Pilot Program):

The Power Your Drive program is very similar to the EV charging programs run by SCE and PG&E. The program is designed to increase the adoption of EVs and integrate the charging of EVs with the grid at an hourly rate. Power Your Drive seeks to satisfy this objective by installing up to 3500 EV charging stations at apartments, condominiums, and places of work. Under the terms of Power Your Drive, SDG&E maintains ownership of the infrastructure to simplify the experience for customers who desire to charge infrastructure and ensure the charging network's reliability.

Table 2-2: Summary of the e-Mobility programs by the California utilities

Summary of the Programs	SCE – Charge Ready	PG&E – EV Charge Network	SDG&E – Power Your Drive
Number of chargers to be deployed under the program	1,500	7,500	3,500
Budget	US$22 million	US$130 million	US$45 million
Eligibility	Public, multi-unit dwellings (MUD) and	MUDs and workplaces	MUDs and workplaces
Disadvantaged communities	10% or greater are reserved for the disadvantaged communities	15% or greater are reserved for the disadvantaged communities	10% or greater are reserved for the disadvantaged communities
Minimum number of chargers per site	10	10	10 at workplaces and 5 at MUDs
Ownership of charger	Host	Host or Utility	Utility
Cost to host	Charger costs, charger installation costs, operations, maintenance and network costs		
Pricing	Pass through pricing or custom pricing	Pass through pricing or custom pricing	Pass through pricing or custom pricing

Source: SDG&E

2.1.2 Germany

Germany has a significant presence in the production of vehicles and has become a centre for significant research and development in the EV market. The German government introduced cleaner technology to provide a big boost to the country's adoption of e-mobility. In February 2010, the Federal Ministry of Economics and Technology (BMWi) established a dedicated coordination office for e-mobility with the Federal Ministry of Transport, Building and Urban Development (BMVBS) under the guise of the Joint Electric Mobility Department (GGEMO). Federal Government created a National electric mobility platform comprising seven working groups, including 20 members, to guide and formulate the EV roadmap.

Policy roadmap for electric mobility in Germany:

Germany has set the goal of becoming the leading market for e-mobility by 2020 as part of its long-term zero-emission mobility vision. As per its National e-mobility development plan, Germany plans to have one million EVs on the road by 2020. Other targets set by the federal government include:

- The target of achieving a 40% reduction in CO_2 emission levels, accounting for 34 million tons by 2020
- Achieving battery density by volume level of 280 to 300 Wh/L by 2025 as part of technical development of third and fourth generation batteries

Incentives for EVs:

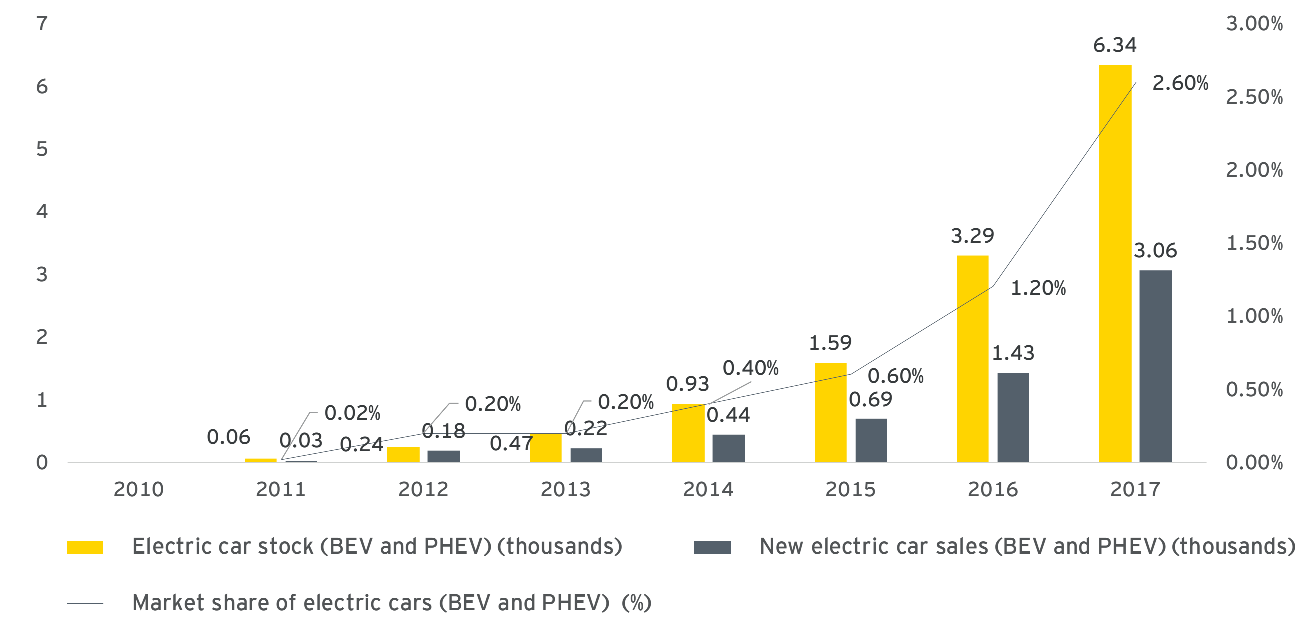
The Key incentives for EVs in Germany are mentioned below:

- Motor vehicle tax exemption
- Company car taxation
- Road traffic measures such as:
    - o Special parking places
    - o Suspension of restricted entry access
    - o Authorized use of bus lanes and special traffic lanes for EVs

2.1.3 Finland

Finland is committed to the EU's environmental targets and Kyoto Protocol. As transport causes 20% of GHG emissions, Finland has set dual goals of reducing GHG emissions from traffic and transport by 15% and increasing the transport sector's energy efficiency by 9% from 2005 to 2020. The government also developed a vision for 2050 in which the direct specific emission of cars is supposed to reach 80g-90g CO_2 per km by 2030, 50-60g CO_2 per km by 2040, and 20-30g CO_2 per km by 2050. Finland has aimed to achieve these targets through technological innovations in vehicles and increasing the use of biofuels. The government has set an EV deployment target of 2,50,000 by 2030.

Figure 2-5: Finland EV market 2010-2017



Source: E&Y

Finland launched "The Finnish Transport Services Act" act in 2017. As per the act, all public and private transport service providers are required to give unbiased access to essential data such as routes, timetables, prices, and other related information.

2.1.4 China

China has held a strong lead in electrifying road transport for a number of years. It accounts for almost the entire global stock of electric two-wheelers, buses, and heavy-duty trucks. Today almost every second electric car in the world is in China. The government proposed an upward revision of its New Energy Vehicle (NEV) sales target in 2019, envisioning 25% by 2025.

Vehicle policies:

In 2018, China introduced a mandatory credit policy for vehicle suppliers to boost domestic sales of NEVs. The Ministry of Industry and Information Technology (MIIT) proposed an updated, tightened NEV credit scheme in 2019 by setting new NEVs credit targets for 2021-23 and establishing a new calculation method for NEV credits beyond 2021.

Table 2-3: EVSE stock in China province wise as of July 2020

Province	No. EVSE	Province	No. EVSE	Province	No. EVSE
Beijing	61,000	Anhui	15,000	Jilin	2,000
Tianjin	23,000	Fujian	1,000	Heilongjiang	2,000
Hebei	23,000	Hubei	11,000	Mengdong	2,000
Jibei	18,000	Hunan	12,000	Shanxi	18,000
Shanxi	13,000	Henan	24,000	Gansu	2,000
Shandong	33,000	Jiangxi	6,000	Qinghai	1,000

Province	No. EVSE	Province	No. EVSE	Province	No. EVSE
Shanghai	51,000	Sichuan	5,000	Ningxia	1,000
Jiangsu	16,000	Chongqing	6,000	Xinjiang	2,000
Zhejiang	43,000	Liaoning	6,000	Non-SGCC Area	173,000
Total					570,000

Source: State Grid Corporation of China

Shenzhen has organized a variety of local schemes for EV adoption and the establishment of charging infrastructure. Close to 500 million yuan (US$ 80 million) was spent by the Shenzhen government per year from 2009 to 2015 towards subsidy for EV cars. As a result, the electric buses in Shenzhen are fully electrified since December 2017. Currently, there are 16,359 electric buses in Shenzhen. Apart from the fiscal incentives, Shenzhen has also provided other incentives such as preferential parking spaces and registration relaxations for encouraging EV uptake. As a result, the city is one of the pioneers in the world for the electrification of bus fleets. (BYD, one of the leading lithium-ion batteries and EV manufacturers, is headquartered in Shenzhen).

Shenzhen provides CNY 400 (USD 60)/kW in subsidies for DC charging facilities, CNY 200/kW (USD 30) for AC charging facilities over 40 kW, and CNY 100/kW (USD 15) for those under 40 kW. In addition, the State Grid Corporation of China (SGCC) has announced plans to increase investment in charging stations.

Charging infrastructure policies: In March 2019, the Ministry of Finance, the MIIT, and the National Development and Reform Commission issued a new subsidy policy. It sets out the aim to shift from subsidizing local vehicle purchases to supporting infrastructure roll-out. As a result, China has been promoting three types of EV charging infrastructure:

- Publicly accessible charging in cities
- Private charging in residences
- Enterprise/company-based charging

Standardization Administration of China (SAC) is the governing body for the EV infrastructure, which forms four levels of Chinese standards:

- National level standards: GB/GBT
- Ministry standards: JB/JBT, YY/YYYT, etc.
- Provincial standards: DB/DBT
- Enterprise's standards: QB/QBT

Out of the four standards, national standards and enterprise standards are used for the e-mobility sector in China. The list of GB/T standards are adopted in China mentioned below:

Table 2-4: GB/T standards adopted in China

Sl No	Standard/Specification	Description
1	GB/T18384	EV safety requirements: Part 1: Energy storage Part 2: Function and protection Part 3: Electric shock protection
2	GB/T 4094	Symbol of operator, indicator and signal of EV
3	GB/T 19596	Electric vehicle terminology

Sl No	Standard/Specification	Description
8	GB/T 27930	Communication protocols between off-board conductive charger and battery management system for electric vehicle
4	GB/T 19836	Electric vehicle instrument panel
5	GB/T18488.1-2006	Motor and its controller: Part 1: Specifications Part 2: Test procedures
6	GB/T18487	Part 1: Conductive charging system general requirement Part 2: Connect requirement of EV and DC charger Part 3: AC/DC charger (and charger station)
7	GB/T 20234	Part 1: Connection set for conductive charging of electric vehicles - general requirements Part 2: AC charging coupler Part 3: DC charging coupler

Source: State Grid Corporation of China

2.1.5 Japan

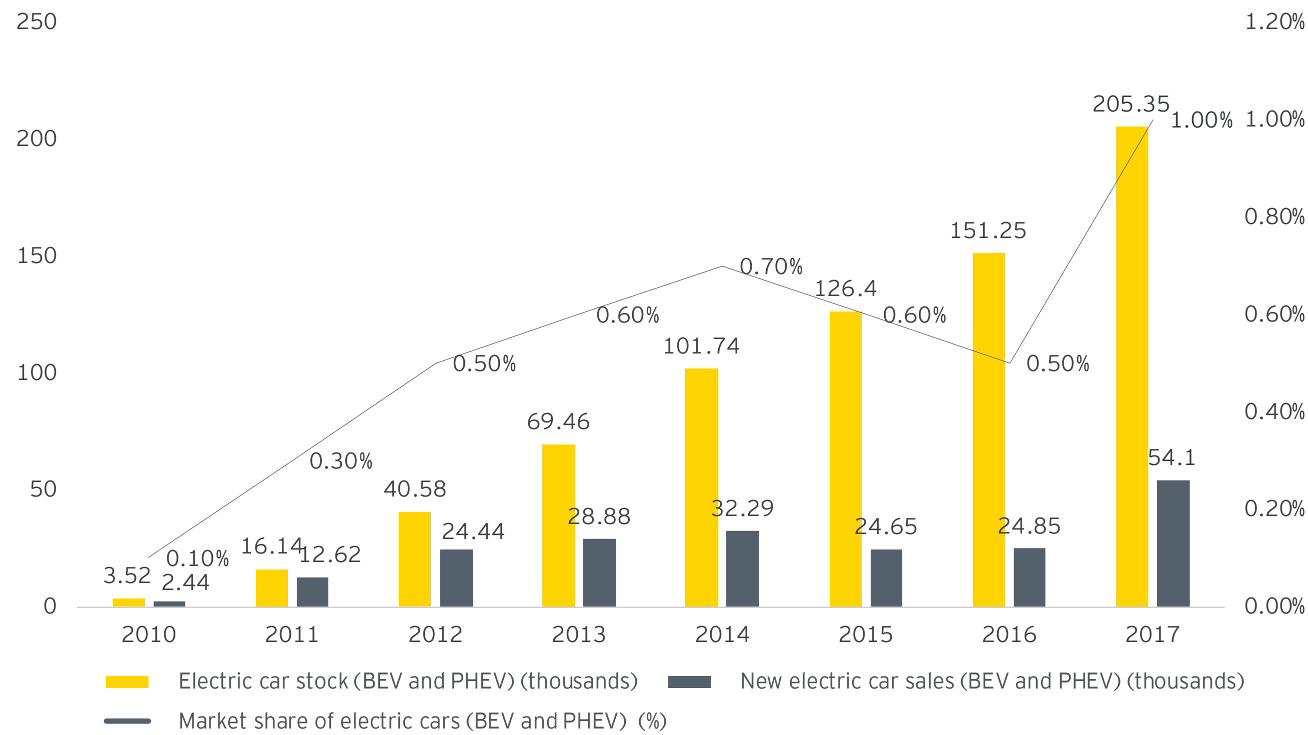
Japan boasts of an EVSE (quick charging points) to EVs ratio of 0.039. The country has 5,990 public quick-charge stations. Non-residential slow charger points are at 17,260, just 1% of Japan's two million slow chargers target. However, Nissan reported that the number of charging points, including domestic chargers, surged past 40,000 compared to 35,000 petrol stations.

Role of utility:

Tokyo Electric Power Company (TEPCO), the largest electric utility in Japan, initiated the formation of the "CHAdeMO Association" to disseminate charging infrastructure to promote the adoption of EVs in Japan. CHAdeMO's members are spread across the value chain and include:

- Automobile manufacturers
- Electric power companies
- Charger manufacturers
- Charging service operators
- Local governments/prefectures

Figure 2-6: Japan EV market growth



Source: E&Y

The major operators in EV charging stations are Nippon charge network, which manages the installation and promotes other charger installers to join the network. Also, they manage payment systems for EV charging and smart user cards based on the type of the charger used. Utilities have been involved in the development of EVSE in Japan. CHAdeMO protocol is based on TEPCO's patented high-voltage (up to 500 V DC) high current (125 A) fast charging via a Japan Automobile Research Institute (JARI) DC fast-charge connector.

2.1.6 Norway

Norway is a pioneer of the EV revolution in its efforts to reduce GHG emissions. The power system of Norway is primarily run-on hydropower, and they are promoting EVs with clean electricity from hydro resources. In addition, Norway provided many progressive incentives for EV deployment that include tax and toll exemptions, preferential parking benefits, and free charging at certain EVSE stations. The government has also invested significant funds for enabling charging infrastructure on highways.

- Oslo City is the global leader in terms of EV market penetration. Oslo has set defined targets EV to reduce GHG emissions by 40% from the transportation sector in its climate budget and has implemented various passenger traffic restrictions to curb GHG emissions
- Oslo has granted a number of fiscal incentives for promoting EV deployment that includes relaxation on import duties and purchases tax on EVs, and lowering or complete removal of taxes on toll and leasing. They also defined strict "low-emission zones," provided free parking for EVs at municipal parking spaces, implemented subsidized EV charging tariffs, and granted "special lane access" for e-buses

- Oslo has invested heavily in public and private charging infrastructure installation and EV research through collaborations with private sector companies and various research organizations

Norway has implemented several initiatives to promote e-mobility:

- **Lower tax:** EVs are subject to reduced circulation or road tax, and are exempt from VAT and other charges like registration fees. Moreover, the tax on company EVs is 50% lower than for traditional cars. Annual motor vehicle tax/road tax is lower too
- **Free parking:** Municipality-owned parking lots offer free parking for EVs
- **Free or discounted road tolls and ferry costs:** Most toll roads and ferry services were also free for EVs
- **Special transport lanes:** EVs enjoy access to dedicated, fast-moving lanes for public transport
- **Free battery-charging points:** An increasing number of publicly-funded charging stations allow EV users to charge their cars for free

2.1.7 Denmark

The Danish government has allotted huge budgetary support for e-Mobility. Currently, Denmark has 20,000 EVs out of 2.5 million total vehicles. By 2030, the nation plans to have over 1 million EVs on the highways with a cumulative budget of $904 million. In addition, Denmark exempts EV owners from paying for public parking spaces. The Danish government issued a rule exempting electric cars from parking fees for up to DKK 5000 per year.

To help put 1 million EVs on the road, they have introduced a tax initiative that gradually increases the taxes and fees for combustion-powered vehicles and lowers taxes for EVs and chargers.

2.1.8 Canada

Canada has set a zero-emission vehicle target of 100% of new vehicle sales by 2040. The national government provides a comprehensive suite of measures to support these targets, ranging from consumer awareness, infrastructure development, and deployment to purchase incentives. For example, in the 2019 budget, CAD 130 million (USD 97 million) was allotted to support the deployment of ZEVs over five years (April 2019 to March 2024).

Federal level vehicle policies: The national government has set ambitious targets for transforming the transport sector. The targets are to reach ZEV sales of 10% by 2025, 30% by 2030, and 100% by 2040.

Provincial-level vehicle policies: Provinces in Canada have the right to adopt policies and incentives on top of existing incentives at the federal level. British Columbia and Québec are the only provinces that currently offer financial incentives for the purchase of ZEVs. The Québec government approved a budget for 2020-21 that allocates additional funding to support ZEVs deployment.

Charging infrastructure policies: The federal government allocated CAD 180 million (USD 130 million) in the 2016-17 budget to support the development of a coast-to-coast fast-charging EV network along with the national highway system, natural gas refuelling stations along freight corridors, hydrogen refuelling stations in metropolitan areas, demonstration of next-generation charging technologies and the development of enabling bi-national codes and standards. In 2019, CAD 130 million (USD 97 million) was allocated in the new Zero-Emission vehicle infrastructure program to support the deployment of charging in public places, multi-unit residential buildings, workplaces, and commercial areas, as well as for fleets and transit applications.

2.1.9 Chile

Chile has a relatively low-carbon electricity mix which offers opportunities to electrify parts of the transport sector to reduce CO_2 and pollutant emissions. Significant progress in deploying EVs has been made over the past three years. In addition, Chile has set short and long-term targets for the electrification of private cars and public transport.

Vehicle policies: Chile's Energy Roadmap 2018-2022 targets to increase the existing number of electric cars tenfold by 2022. Their national e-mobility strategy includes targets to electrify 100% of public transport by 2040 and achieve a 40% penetration rate of electric cars in the private stock by 2050.

Charging infrastructure policies: The government set a goal to install 150 publicly accessible charging points and another 112 by public-private partnerships by the end of 2019. In addition, the Ministry of Energy mandated to regulate the inter-operability of the EV charging infrastructure.

Industrial policies: The government is strongly promoting the domestic lithium industry. This support extends from raw material extraction through the production of lithium-based products by national and foreign companies, specifically focusing on EV batteries.

2.2 Types of Chargers Used in Different Countries

2.1.10 South Korea

The South Korean government has set high goals for its EV industry over the next ten years and is making heavy investments in vehicles and infrastructure. The government announced in 2019 that it would be providing the equivalent of about $900 million in subsidies for electric and fuel cell cars and infrastructure. In addition, 738.2 billion won ($609 million) would go to BEV subsidies and infrastructure, while 359.3 billion won ($296 million) would be earmarked for fuel cell electric vehicles (FCEVs) and hydrogen fueling stations.

Hydrogen is a key focus in the government's goals to decrease dependency on fossil fuels and increase the performance of its EV industry. In January 2019, South Korea announced its target of having 80,000 fuel cell cars on the roads by 2022, and these new subsidies will contribute to that goal. In 2020 alone, the government aims to increase the number of BEVs in the country by over 70,000 and the number of FCEVs by 10,000. To facilitate this, purchases of these vehicles will be eligible for subsidies between 8 million and 22.5 million won ($6,600 to $18,600). In terms of infrastructure, South Korea aims to increase hydrogen fueling stations to 660 by 2030 and EV charging stations to 15,000 by 2025.

Table 2-5: Types of chargers used in different countries

	Conventional plugs	Slow chargers		Fast chargers	
Level	Level 1	Level 2		Level 3	
Current	AC	AC		AC, tri-phase	DC
Power	<= 3.7 kW	> 3.7 kW and <= 22 kW	<= 22 kW	> 22 kW and <= 43.5 kW	Currently < 200 kW

	Conventional plugs	Slow chargers		Fast chargers		
California	Type B; SAE J1772 Type 1	SAE J1772 Type 1	Tesla	(Under development) SAE J3068	CCS Combo 1 (SAE J1772 and IEC 62196-3)	Tesla and CHAdeMO (IEC 62196-3 Type 4)
Germany	Type C/F/G	IEC 62196-2 Type 2 Tesla	IEC 62196-2 Type 2	CCS Combo 2 (IEC 62196-3) 62196-3)	CCS Combo 2 (IEC 62196-3) 62196-3)	Tesla and CHAdeMO (IEC 62196-3 Type 4)
Japan	Type B	SAE J1772 Type 1	Tesla		Accepts all IEC 62196-3 standards	Tesla and CHAdeMO (IEC 62196-3 Type 4)
China	Type 1	GB/T 20234 AC	Tesla		GB/T 20234 DC	

2.3 Deploying Electric Buses in Cities

The highlights of four cases of city fleets operating in the public transit systems of Helsinki (Finland), Kolkata (India), Santiago de Chile (Chile) and Shenzhen (China) is presented in the Table below:

Table 2-6: Electric bus case studies from four cities across the world

Sl No	City Profile	Buses	Chargers	Implementation
1	Helsinki introduced electric buses in 2017. Its a public transit system accommodating 370 million trips per year, a third of these on its 1,400 buses.	In 2019, there were 48 electric buses (Made by Linkker, Yutong, VDL) in operation. The e-bus fleet is set to quadruple by 2021. Helsinki aims to electrify 30% of its bus fleet by 2025.	E-buses use a mix of pantographs and fixed EVSE for charging under different regimes: 15 buses are equipped with pantographs and use opportunity charging while 33 buses charge at depots.	The regional public transport authority, Helsinki Region Transport (HSL), has promoted the roll-out of electric buses.
2	Kolkata metro region has 925 bus routes and over 11,000 buses to serve about 14 million residents. The government-owned West Bengal Transport Corporation (WBTC) operates 1,553 of the buses on 348 routes.	Since 2019, WBTC has put 80 e-buses supplied by Tata Motors into operation on 12 routes. Another 150 vehicles will enter service in 2020-21. WBTC aims too fully electrify its fleet of about 5,000 buses by 2030.	Buses are charged at ten depots, most of which are equipped with 7-8 chargers with power rating of 60 kW or 120 kW. All routes have one or two additional chargers at the line terminus.	WBTC's roll out of e-buses and chargers was made possible through the FAME I scheme of GoI which made funds available for procurement of 80 e-buses with charging equipment. 40 of these are 9m buses with 125 kWh battery packs and 40 are 12m buses with 88 kWh battery packs.
3	Santiago de Chile has 6,756 buses on 380 routes that play a key role in its public transit system. The city's first e- buses started service in 2019.	Santiago has over 400 e-buses (6% of its fleet) and aims to transform its entire public bus fleet to electric by 2040. In 2019 operator Metbus leased 285 BYD's e-buses for ten years from energy company Enel X. Metbus' electric fleet is set to expand to 435 in 2020.	The existing e-bus fleets use depot charging. Operator's lease chargers served with renewables-based electricity from Enel X and Engie. Metbus buses use about 160 chargers of 80 kW each.	Santiago's decision to adopt the Euro VI standard in 2018 for buses laid the groundwork for e-bus deployment.
4	Shenzhen, in 2019, became one of the first cities to have transformed its 100% bus fleet to electric buses. With a fleet size of 16,500+ buses, distributed among three bus operators (Shenzhen bus group, Shenzhen eastern bus company and Shenzhen western bus company).	Of the three operators, Shenzhen Bus Group (SBG), introduced e-buses in three stages, starting in 2011 with 127 e-buses, reaching 545 by 2015 to an all-electric fleet of more than 6,000 buses by end of 2017.	Buses charge overnight at depots. Only a few buses on long routes get a 30-minute extra charge during the day. Charging operators have more than 1,700 chargers of 150 kW and 180 kW at 104 terminals and depots.	The local government mandated fleet electrification and offered purchase subsidies of up to CNY 1 million (USD 140 000) per bus.

Source: IRENA

3 ELECTRIC VEHICLE CHARGING INFRASTRUCTURE IN INDIA

3.1 Standards for Electric Vehicles in India

The committee formed under the Ministry of Heavy Industries in 2017 has issued a standardized protocol for EV Charging Infrastructure (EVCI) named “Bharat Public Charger Specifications” with detailed specifications of AC and DC chargers. In addition, the communication architecture specified Open Charge Point Protocol (OCPP) as the communication protocol for public off-board chargers.

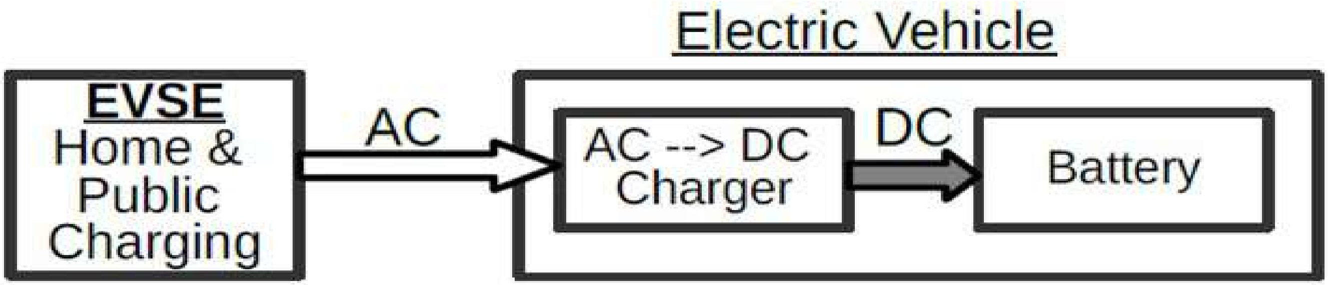
Normal AC charging:

The electric 2, 3, and 4-wheelers in India do not have onboard EV chargers beyond 2.5 to 3 kW with 230 V single phase charging point requirements to make the vehicles affordable. These AC 2.5 to 3kW, could fast charge a 2-wheeler in one-hour time and a 4-wheeler with a 12 kWh battery in five to six hours[7].

AC charger - AC 001

- No. outputs - 3
- No. of vehicles charging simultaneously - 3 (15A each)
- Connector compatibility - IEC60309

Figure 3-1: Normal AC charging



Fast AC charging:

Global electric cars like the Nissan Leaf or the Tesla have onboard chargers with higher power ratings. This feature enables AC charging at a faster rate from 7.7 kW to 22 kW.

AC plug connectors:

Indian electric cars use the IEC 60309 industrial blue connectors, and Bharat EV specifications recommend using this plug.

DC charging:

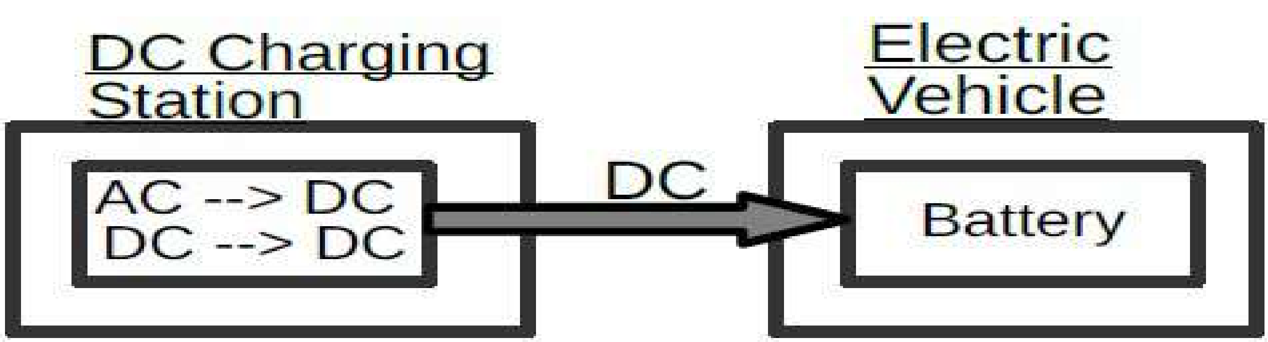
The DC off-board chargers are classified as level 1 and level 2 DC chargers with:

- Level 1 DC chargers have an output voltage of 48/60/72 V and power output of 10 kW to 15 kW with a maximum current of up to 200 A
- Level 2 DC chargers have an output voltage of 1000 V with a power output of 30 kW to 150 kW

DC charger - DC 001 (Level 1)

- No. outputs - 2
- No. of vehicles charging simultaneously - 1
- Connector compatibility - One connector with GB/T 20234.3 and another to be defined

Figure 3-2: Normal DC charging



DC plug connectors:

There are four DC fast charging connectors currently being used by electric car manufacturers all over the world.

- CHAdeMO: Nissan and other Japanese EVs
- SAE Combo Charging System (CCS): BMW, GM, VW, and other OEMs
- Supercharger: Tesla standard connector
- GB/T: All Chinese companies use this. Mahindra and Tata electric cars also use this standard

Bharat EV charger DC 001 specifications recommend the Chinese GB/T connector standard. Also, Indian electric cars and electric buses use the GB/T port on the vehicles for DC fast charging.

CHAdeMO Connector

CCS Connector

GB/T Connector

3.2 Standardization Work by Bureau of Indian Standards

On the recommendation of ISGF, the Bureau of Indian Standards (BIS) set up ETD 51 committee in 2016 for preparing the Indian standards for EVSE. The EVs need to be connected to the electric grid for charging the battery and hence must comply with the electricity grid code like any other electrical equipment. Characteristics of the Indian power system are similar to that of Europe 230 V and 50Hz (unlike America: 110 V and 60Hz) and follow IEC standards. ETD 51 committee, with the participation of all relevant stakeholders, had extensive deliberations and have finalized standards mentioned in the below Table.

Table 3-1: Indian standards for EVSE

Indian Standards	Description	Status (As of June 2021)
IS 17017 series of standards	Primarily based on IEC 61851; IEC 62196 IS 17017 recommends AC Type-2 including system A and system C chargers	
IS 17017-Part 1	General requirements and definitions of EVSE	Published in July 2018
IS 17017-Part 2-1 IS 17017-Part 2-2 IS 17017-Part 2-3	Adapted from IEC 62196 - Part: 1, Part: 2, Part: 3 standards for the plugs, socket outlet, vehicle couplers and vehicle inlets.	Published in 2020

Indian Standards	Description	Status (As of June 2021)
IS 17017-Part 21 Electromagnetic Compatibility (EMC)	Electric vehicle requirements for conductive connection to an AC/ DC supply	Published in September 2019
IS 17017-Part 21-1	On-Board charger	
IS 17017-Part 21-2	Off-Board charger	
IS 17017-Part 23	D.C electric vehicle charging station (Adapted from IEC 61851-23)	Draft has been edited by BIS and sent to ARAI to finalize.
IS 17017-Part 23-1	H-category/ EV buses require generally around 100 kW DC Supply. DC electric vehicle charging station with connection systems	Draft ready
IS 17017-Part 23-2	L-category/ Light EV DC supply. (2W between 1 & 2 kW; 3W between 3 & 5 KW). DC EV supply equipment where protection relies on electrical separation	Draft ready
IS 17017-Part 23-3	M-category/ EV cars require generally upto 50 kW DC supply. DC electric vehicle supply equipment	Draft ready
IS 17017-Part 24	Digital communication between a DC EV charging station and an electric vehicle for control of DC charging	Standards have been finalized -under printing/publishing
IS 17017-Part 3	Communications for EV infrastructure management	Under development
IS 17017-Part 3-1	EVSE to the charge point aggregator	Under development
IS 17017-Part 3-2	Charge point aggregator to utility central management system	Under development
IS 17017-Part 4	Connection systems	Draft ready
IS 17017-Part 4-1	General requirements, comprising clauses of a general character that apply to all four modes of EV charging	Draft ready
IS 17017-Part 4-2	Dimensional compatibility and interchangeability requirements for AC pin and contact-tube accessories	Draft ready
IS 17017-Part 4-3	Dimensional compatibility and interchangeability requirements for DC and AC/DC pin and contact-tube vehicle couplers	Draft ready
IS 17017-Part 4-4	Light EV (AC & DC) connection systems	Under development
IS 17017-Part 4-5	Combined connection systems for medium power DC (Type-2; configuration DD)	Under development
IS 17017-Part 4-6	Heavy EV connection systems (AC+DC combined connection system and automated high-power DC connection systems)	Under development
IS 17017-Part 5	Grid connectivity and EVSE networks	Under development
IS/ISO 15118	Communication between EV and EVSE	6 volumes adapted as it is and published in 2019

Source: Department of Science and Technology and BIS

3.3 E-Mobility Status in India

The government of India launched Transformative Mobility and Energy Storage Mission under NITI Aayog in 2019. Apart from that, 18 states in India have also issued state-specific electric mobility policies.

3.3.1 Government Initiatives on Charging Stations

Under the FAME II scheme, DHI allotted 2,636 charging stations (1,633 fast-charging stations and 1,003 slow charging stations) for 62 cities across 24 States/UTs under FAME II[8] which is given in the Table below.

Table 3-2: State-wise allocated EV charging stations across India

Sl No	States/UTs	No. of EV Charging Stations Allocated	Sl No	States/UTs	No. of EV Charging Stations Allocated
1	Maharashtra	317	13	Chandigarh	70
2	Andhra Pradesh	266	14	Haryana	50
3	Tamil Nadu	256	15	Meghalaya	40
4	Gujarat	228	16	Bihar	37
5	Rajasthan	205	17	Sikkim	29
6	Utter Pradesh	207	18	Jammu & Kashmir	25
7	Karnataka	172	19	Chhattisgarh	25
8	Madhya Pradesh	159	20	Assam	20
9	West Bengal	141	21	Odisha	18
10	Telangana	138	22	Uttarakhand	10
11	Kerala	131	23	Puducherry	10
12	Delhi	72	24	Himachal Pradesh	10
Total					2,636

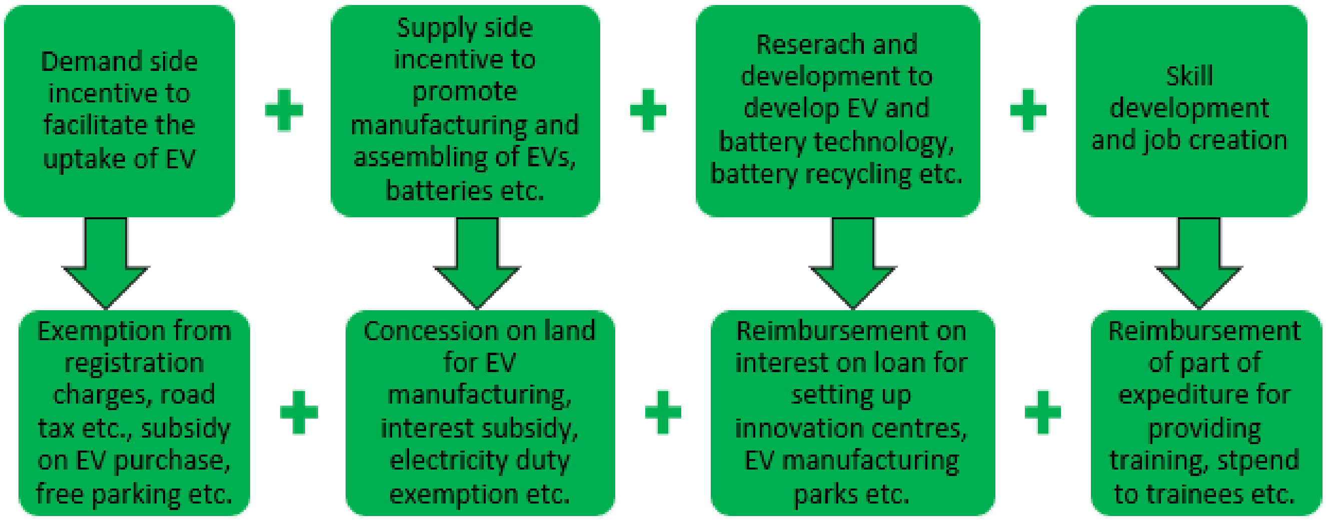
Source: dHI

3.3.2 Electric Vehicle Policies in the Various States in India

Apart from central government, 18 state governments like Delhi, Karnataka, Uttar Pradesh, Andhra Pradesh, Kerala, Telangana, Tamil Nadu, Bihar, Uttarakhand, West Bengal, Gujarat, Maharashtra etc. have issued state-specific policies focusing on manufacturing and deployment of electric vehicle and charging infrastructure in the state.

8 Press Information Bureau, Government of India: https://bit.ly/3joa0Ra

Some of the key aspects of these state policies that provides the impetus for uptake of electric vehicle and charging infrastructure are as shown below:



The detailed policy incentives of various states across India are given in Annexure - II.

4 ELECTRIC VEHICLE CHARGING INFRA-STRUCTURE IN BESCOM

4.1 Introduction

Karnataka has a better ecosystem for a vibrant automotive sector with large pool of technical manpower, robust R&D capabilities, and manufacturing expertise. Karnataka is the first state in India that issued an electric vehicle policy in September 2017 to make Bengaluru the EV capital of India. The policy aims to generate investments of INR 310 billion in EV R&D and manufacturing. To achieve Karnataka electric vehicle and energy storage policy objectives 2017, BESCOM has taken the initiative to set up EV charging stations in Bengaluru City.

Karnataka EV policy objectives:

- Maintain the lead share of Karnataka as a preferred destination for attaching investment on manufacturing of EVs
- Attract investments of INR 310 billion and create employment opportunities for 55,000 people both from the supply and demand side
- Create a conducive environment for transition to EV environment from IC engines

4.1.1 EV Target by 2030 in Bengaluru City

Karnataka's EV policy aims to convert 50% of its entire fleet into EVs by 2030, thus shifting the focus to the electrification of transportation to usher in the era of green mobility[9].

Table 4-1: EV target by 2030 in Bengaluru City

Vehicle Type	Total Vehicular Population (Prediction for 2030 using CAGR)	EV Target for 2030	EV (%)
Two-wheeler	1,86,87,175	93,43,588	50%
Three-wheeler	4,99,667	2,49,833.3	50%
Four-wheeler	48,14,641	24,07,320	50%
Buses	1,17,800	58,900.18	50%
Total	2,41,19,283	1,20,59,641	50%

Source: B-PAC

4.2 BESCOM Plan for Electric Vehicle Charging Stations

BESCOM has prepared a plan for installing 678 charging stations for 4W (Light motor vehicles) across Karnataka. 162 of those EVCS have been proposed for Bengaluru city. The existing 136 charging points at 74 locations are in Bengaluru mentioned in Table 4-2 below. Under FAME scheme BESCOM plans to set up charging stations at every 20-25 km distance on either side of the road along the Bengaluru -Tumkur highway and the Bengaluru-Mysore highway. The charging stations would be mostly set up in the premises of government buildings. Additionally, BESCOM plans to procure 25 more EVs, for which four additional chargers will be set up at its corporate office.

4.3 Type and Number of Chargers in Existing EVCS

Table 4-2: Chargers installed in Bengaluru City

Sl No	Name of the Office	Department	AC Charger	DC Charger	Total Chargers
1	BESCOM - Devanahalli SDO	BESCOM	1		1
2	BESCOM - Hosakote SDO	BESCOM	1		1
3	RTO Nelamangala	Transport Department	1		1
4	BBMP Vignananagara Office	BBMP	2		2
5	RTO KasthuriNagar office	Transport Department	2		2

9 https://bpac.in/sustainable-mobility-for-bengaluru-report-march-2020.pdf

Sl No	Name of the Office	Department	AC Charger	DC Charger	Total Chargers
6	BESCOM - E6 Indiranagar SDO	BESCOM	1	2	3
7	BDA Domlur Complex	BDA	1		1
8	TTMC Domlur	BMTC	2		2
9	BESCOM -Tannery Road	BESCOM	1		1
10	BBMP Ward 194 Gottigere (Next to royal county park)	BBMP	2		2
11	TTMC Shivajinagar	BMTC	1		1
12	BDA HBR layout complex	BDA	1		1
13	BESCOM -Lingarajapuram O&M	BESCOM	1		1
14	BESCOM - E8 Banasawadi SDO	BESCOM	1	2	3
15	BBMP Horamavu Office	BBMP	2		2
16	BESCOM -Nagawara Sub Division	BESCOM	1		1
17	BESCOM -Corporate Office - 2	BESCOM	1	4	5
18	KPTCL W4 Subdivision	KPTCL	2		2
19	BESCOM - Mahadevapura SDO	BESCOM	1	2	3
20	BBMP Mahadevapura Office	BBMP	1		1
21	BBMP Whitefield Office	BBMP	1		1
22	TTMC Whitefield	BMTC	2		2
23	BBMP KR Puram Office	BBMP	1		1
24	RTO K R Puram Office	Transport Department	2		2
25	RTO Yelahanka	Transport Department	2		2
26	BESCOM - C7 SDO	BESCOM	1	2	3
27	BBMP Sahakara nagara Office	BBMP	2		2
28	BESCOM - Jalahalli SDO	BESCOM	1		1
29	BESCOM -Vidyaranyapura SDO	BESCOM	1		1
30	BESCOM - Bagalagunte O&M	BESCOM	1		1
31	TTMC Yeshawanthapura	BMTC	3		3
32	BESCOM - C6 Mathikere SDO	BESCOM	1	2	3

Sl No	Name of the Office	Department	AC Charger	DC Charger	Total Chargers
33	BESCOM - N4 Peenya SDO	BESCOM	1	2	3
34	BESCOM - Hegganahalli O&M	BESCOM	1		1
35	KSRTC Peenya	KSRTC	2		2
36	BESCOM - Peenya SRS O&M	BESCOM	1		1
37	BESCOM - Shettihalli (Peenya) O&M	BESCOM	1		1
38	BESCOM - Chandapura Sub Division	BESCOM	2		2
39	KIADB Jigani I. A	KIADB	2		2
40	BBMP office (Next to Traffic Police Station, Gottigere Main Road)	BBMP	1		1
41	RTO Electronic City	Transport Department	2		2
42	BBMP Doddakanneli Office	BBMP	2		2
43	BBMP Vijaya Bank L/O (Bilekahalli)	BBMP	1		1
44	BESCOM - HSR Division Office SDO	BESCOM	2	2	4
45	BBMP Jayanagar office	BBMP	1		1
46	BESCOM - BTM L/o O&M	BESCOM	1	2	3
47	BBMP Ward 177 Office (Near BoB)	BBMP	1		1
48	BESCOM - Katriguppe SDO	BESCOM	1	2	3
49	BESCOM - Chikkalasandra O&M	BESCOM	1		1
50	BBMP Corporation office,	BBMP	3		3
51	TTMC Shantinagar	BMTC	2		2
52	BESCOM - ISRO Layout O&M	BESCOM	1		1
53	BESCOM - Murugeshpalya S17 SDO	BESCOM	1	2	3
54	BDA Banashankari	BDA	1		1
55	TTMC Kengeri	BMTC	2		2
56	BESCOM - Kumbalagodu O&M	BESCOM	1		1
57	BESCOM - Kaggalipura SDO	BESCOM	2		2
58	BESCOM -RR Layout O&M	BESCOM	1		1

Sl No	Name of the Office	Department	AC Charger	DC Charger	Total Chargers
59	RTO Jnanabharti	Transport Department	2		2
60	TTMC Vijayanagar	BMTC	3		3
61	BESCOM - West Circle Office	BESCOM	1		1
62	BESCOM - Papareddy Palya O&M	BESCOM	1		1
63	BESCOM -Mallathalli O&M	BESCOM	1		1
64	BDA Nagarabhavi	BDA	2		2
65	BESCOM - Avalahalli SDO	BESCOM	1		1
66	BESCOM - Shankarapuram O&M	BESCOM	1		1
67	BESCOM - Bytarayanapura SDO	BESCOM	2	2	4
68	KSRTC Mysore Road Satellite	KSRTC	2		2
69	BESCOM - W7 - SDO	BESCOM	1		1
70	BBMP Thyagarajanagara Office	BBMP	2		2
71	BESCOM Corporate Office-1	BESCOM	1	2	3
72	KERC, Vasantnagar	BESCOM	1		1
73	Vidhana Soudha	BESCOM	1	2	3
74	Vikasa Soudha	BESCOM	1	2	3
Total			104	32	136

Source: BESCOM

4.4 Impact of EVs on the Distribution Feeders

Increasing EV charging load poses several challenges for the electricity distribution system. These challenges have been thoroughly evaluated in this study. EV impact analysis is primarily conducted to evaluate the effects of EVs on the electricity generation adequacy, transformer aging, and power quality. It is hypothesized that EV charging during peak load hours will increase the demand for peak loads and require the augmentation of generation, transmission, and distribution system capacities. The increased demand for EV loads will overload substation and distribution transformers, thereby degrading the life of the transformers. In addition, EV charging can lead to many problems with power quality, such as voltage drops, power imbalances, and voltage/current harmonics.

4.4.1 EV Load Impacts on Electricity Generation Adequacy

Several EV integration studies have evaluated the existing and expected generation capacity to meet current and future EV demands. These studies suggest that the new power plants would not be required to meet the EV charging demand if EVs are charged during off-peak hours. If the charging of vehicles is regulated and moved to off-peak hours, EV charging will not increase the demand for system peak load and thus will not impact the adequacy of power generation. However, without regulated charging, the rollout of large-scale EVs will overload the system and require increased generation capacity. In particular, EV charging may require additional power generation and capacity enhancement of transmission and distribution infrastructure depending on the time and location of vehicle additions. The reliability of generation will be a significant challenge in these situations.

4.4.2 EV Load Impacts on Distribution Grid Equipment

Large-scale EV deployment in the distribution system is likely to cause issues such as increased demand, increased system losses, and additional voltage drops. The increased demand would overload distribution transformers (DTs), worsen the life of the transformers, and increase system losses due to EV loads. Furthermore, new peak loads exceeding the rated capacity of the DTs generated by EV charging will accelerate the ageing of the DTs. It characterizes, in particular, the influence of EV charger harmonics on the DT's life. Smart or controlled EV charging is required to minimize transformer overloading. For instance, continuosly increased peak load demand will decrease the transformer's life expectancy. If EVs are mainly charged during off-peak hours, a better load profile could minimize the overloading hours on the DTs, resulting in a positive effect on the DT life. Likewise, the cables may also be affected by overloading and harmonic injection.

4.4.3 EV Load Impact on Power Quality

EV charging is likely to cause power quality problems in the distribution circuit, including, but not limited to, under-voltage situations, power imbalances, and voltage and current harmonics. An EV load charged by a level 2 charger would nearly double the peak load demand of the homeowner. In the secondary service voltages, the increased load demand due to EVs leads to more voltage drops, thus affecting the efficiency of the service voltage. Numerous studies have been carried out in order to assess the effects of EV charging on delivery voltages. It is concluded on the basis of the studies that a large scale EV deployment could violate suggested secondary wire voltage limits and could cause voltage imbalance. This study included modelling and load flow analysis on 12 feeders where EV charging stations are installed in Bengaluru. Also, the analysis of this study underscores the same findings that EV charging induces harmonics in the distribution grid that need to be mitigated to maintain acceptable voltage levels for customers.

5 ELECTRIC VEHICLE CHARGING INFRA-STRUCTURE PLANNING STUDY

5.1 Study Methodology

To identify potential technical issues and grid impacts of the EVCS on the distribution grid, the project conducted a detailed load flow analysis on 12 distribution feeders of BESCOM in Bengaluru City. The impact on the grid varies according to their geographical locations and feeder network topologies across the city. For each feeder, the following data has been collected:

I. 11 kV feeder Single Line Diagram (SLD)

II. 11 kV feeder peak load recorded in 2020

III. Current carrying capacity of the feeder

IV. Conductor/cable characteristics

V. Ratings of Distribution Transformers (DTs)/ capacity and voltage ratios

VI. EV Charging Station (EVCS) details

VII. GIS coordinates of the feeders and EV charging stations

VIII. Solar Rooftop PV (SRTPV) penetration - existing or expected in the near future (by 2022 and by 2025)

The modelling studies were carried out using the CYME DIST software tool (version 9.0). The CYME power system analysis software is a comprehensive suite of advanced simulation tools to address regular and emerging power network planning and operation challenges. The CYME software provides powerful capabilities that support the detailed modelling of any distribution, industrial, or transmission network. It includes balanced and unbalanced networks, secondary grids, substations, low-voltage distribution systems, DC systems, and nested networks. These networks can be radial or meshed and can be represented both geographically and schematically.

The tool provides a wide spectrum of analysis of different simulations including basic analysis such as power flow short-circuit, load allocation, capacitor placement, load balancing and motor starting. In addition, advanced analysis modules facilitate contingency analysis, arc flash hazards, long-term dynamics, Volt/VAR optimization, protective device coordination, transient stability, harmonics, and many more.

The unbalanced three-phase load flow simulation and harmonic analysis have been employed to study system performance for the impact of EVCS on the conventional electrical network. The broad methodology followed for the load flow studies is listed below:

- Scrutinisation of collected network input for selected feeders
- Study and analysis of AS-IS electrical network around the EVCS locations identified and potential sites where EVSCS will be installed
- Load increase on the selected feeders owing to EV load and SRTPV penetration in three different phases (2020/2022/2025)
- Load flow studies on selected feeders with different scenarios of EVCS load and SRTPV
- Harmonic assessment for presence of harmonics on the feeders due to operation of EVCS (AC to DC conversion) and SRTPV inverters
- Assessment of infrastructure gaps and grid upgrade requirements
- Recommendations for network improvement

5.1.1 Steady-State Power Flow Analysis

Power flow analysis is carried out for different scenarios on the existing network to identify abnormal conditions such as overloading of the distribution network etc. with respect to the allowable conditions.

The network analysis has been carried out by allocating the load to power flow on the selected feeder. The load allocation functionality in the model helps to adjust the connected load to match the metered demand. It assigns a portion of the metered demand to each phase in each section according to the (connected or actual) kVA. It divides the metered demand in proportion to the connected capacity. Once the metered demand has been allocated, the load flow is simulated to check the network scenario.

The objective of a load flow model is to analyze the steady-state performance of the power system under various operating conditions. The load flow analysis of a radial distribution feeder requires an iterative technique that is specifically designed and optimized for radial or weakly meshed systems. The voltage drop analysis method includes a full three-phase unbalanced algorithm that computes phase voltages (V_R, V_Y, and V_B), power flows, and currents, including the neutral current.

It indicates when the calculated voltage on any section of the selected networks changes from one iteration to another by more than the tolerance limits. For example: |34465.2 – 34464.8|/34464.8 < 0.1%.

The power flow analysis operates in conjunction with the harmonic analysis to communicate the fundamental frequency voltages and currents for harmonic distortion.

5.1.2 Harmonic Analysis

Harmonic analysis is carried out for different cases on the existing network to evaluate the impact of EVSE and SRTPV on the electrical network according to IEEE 519 - 2014 standards. Integration of EVSE may adversely impact the distribution network due to the nonlinear nature of EV load that generates harmonics, which can cause abnormal operation such as increased losses, reduced efficiency, temperature rise, and premature insulation and winding failures.

The voltage and current distortion limits for different voltage levels are shown in Table 5-1 below as per IEEE standard 519-2014. It allows the harmonic distortions to exceed up to a maximum of 150% of the specified limits for short periods.

Voltage distortion limits:

Table 5-1: Harmonic voltage distortion limits (IEEE 519 – 2014)

Bus Voltage at the Point of Common Connection (PCC)	Individual Voltage Distortion – IDD (%)	Total Voltage (Harmonic) Distortion THD (%)
1.0 kV and below	5.0	8.0
Above 1.0 kV through 69 kV	3.0	5.0
Above 69 kV through 161 kV	1.5	2.5
Above 161 kV	1.0	1.5

Current distortion limits for systems rated 430 V through 11 kV:

Table 5-2: Harmonic current distortion limits (IEEE 519 – 2014)

Maximum Harmonic Current Distortion of IL in (%)						
Individual Harmonic Order (Odd Harmonics)						
ISC/IL	3≤h<11	11≤h<17	17≤h<23	23≤h<35	35≤h<50	TDD
<20	4	2	1.5	0.6	0.3	5
20<50	7	3.5	2.5	1	0.5	8
50<100	10	4.5	4	1.5	0.7	12
100<1000	12	5.5	5	2	1	15
>1000	15	7	6	2.5	14	20
Even harmonics distortions are limited to 25% of the odd harmonic limits						
I_L: Maximum demand load current (fundamental frequency component) at Point of Common Connection (PCC)						
I_{SC}: Maximum short circuit current at PCC						
TDD: Total Demand Distortion						
IHD: Individual Harmonic Distortion						
THD: Total Harmonic Distortion						

5.2 Selection of Feeders for the Modelling Study

The load flow study was conducted on the following 12 feeders:

Table 5-3: List of selected feeders for load flow studies

Sl No	EV Charging Station Location	Space Available (sq meter)	Locality in the City	MUSS Name (Substation)	11 kV Feeder Name	Latitude and Longitude	No. of EVSE Installed (Different types and capacities)	Capacity of the DT Connecting the EVSE (kVA)	Cable Size (in sq mm)
1	Kathriguppe O&M Office	100	Kathriguppe	Arehally (66/11 kV)	F03 It-tamadu	12.926302 N, 77.548129 E	15 kW GB/T + 3.3 kW AC – 01 Nos 25 kW CCS/CHAdeMO - 01 Nos	63	1.1 kV 3.5C XLPE 95SQMM UGC
2	S7 Sub-Division Office	100	Murugesh-palya, HAL	HAL	F07 HAL	12.959385 N, 77.662755 E	15 kW GB/T + 3.3 kW AC - 01 Nos 25 kW CCS/ CHAdeMO - 01 Nos	100	1.1 kV 3.5C XLPE 95SQMM UGC
3	Mahadeva-pura O&M Office	25	Mahadevapura	Hoody	F08 ITI Aux	12.994805 N, 77.699232 E	15 kW GB/T + 3.3 kW AC - 01 Nos 25 kW CCS/ CHAdeMO - 01 Nos	250	1.1 kV 3.5C XLPE 95SQMM UGC
4	N4 Sub-Division Office	25	Peenya	Brindavana	F19 KIADB	13.017574 N, 77.507203 E	15 kW GB/T + 3.3 kW AC - 01 Nos 25 kW CCS/ CHAdeMO - 01 Nos	100	1.1 kV 3.5C XLPE 95SQMM UGC
5	Corporate Office	200	KR Circle	C-Station	F01 C-Station	12.9754648 N, 77.5861657 E	15 kW GB/T + 3.3 kW AC - 04 Nos 25 kW CCS/ CHAdeMO - 01 Nos	100	1.1 kV 3.5C XLPE 95SQMM UGC
6	C7 Sub-Division Office	30	Yelahanka	KHB	F08 Byatha	13.095649 N, 77.594256 E	15 kW GB/T + 3.3 kW AC - 01 Nos 25 kW CCS/ CHAdeMO - 01 Nos	100	1.1 kV 3.5C XLPE 95SQMM UGC
7	Indiranagar Division Office	40	HAL 2nd Stage	Amarjyothi	F04 14th Cross RMU feeder	12.964607 N, 77.644151 E	15 kW GB/T + 3.3 kW AC - 01 Nos 25 kW CCS/ CHAdeMO - 01 Nos	100	1.1 kV 3.5C XLPE 95SQMM UGC
8	E8 Sub-Division Office	25	Banaswadi	Banaswadi	F07 Sub-haihan-palya	13.019835 N, 77.639798 E	15 kW GB/T + 3.3 kW AC - 01 Nos 25 kW CCS/ CHAdeMO - 01 Nos	100	1.1 kV 3.5C XLPE 95SQMM UGC
9	W6 Sub Division	30	W6 Sub Division	Banashan-kari	F25 BSK	12.950615 N, 77.540549 E	15 kW GB/T + 3.3 kW AC - 01 Nos 25 kW CCS/ CHAdeMO - 01 Nos	100	1.1 kV 3.5C XLPE 95SQMM UGC

Sl No	EV Charging Station Location	Space Available (sq meter)	Locality in the City	MUSS Name (Substation)	11 kV Feeder Name	Latitude and Longitude	No. of EVSE Installed (Different types and capacities)	Capacity of the DT Connecting the EVSE (kVA)	Cable Size (in sq mm)
10	HSR Division Office	200	HSR 2nd Sector	HSR	F03 HSR	12.911203 N, 77.648898 E	15 kW GB/T + 3.3 kW AC - 01 Nos 25 kW CCS/ CHAdeMO - 01 Nos	100	1.1 kV 3.5C XLPE 95SQMM UGC
11	C6 Sub-Division Office	30	Mathikere	Mathikere	F07 MTK	13.038109 N, 77.557802 E	15 kW GB/T + 3.3 kW AC - 01 Nos 25 kW CCS/ CHAdeMO - 01 Nos	100	1.1 kV 3.5C XLPE 95SQMM UGC
12	BTM O&M Unit -2	35	BTM Layout	St. John Woods Substation	F01 SJW	12.916733 N, 77.610325 E	15 kW GB/T + 3.3 kW AC - 01 Nos 25 kW CCS/ CHAdeMO - 01 Nos	100	1.1 kV 3.5C XLPE 95SQMM UGC

Source: BESCOM

5.3 Assumptions and Considerations

- The efficiencies of 15 kW DC 001 GB/T, 25 kW CCS2/CHAdeMO, 50 kW DC fast charger and 100 kW charger have been assumed to be 95%
- The output DC voltage for 15 kW DC charger and 25 kW DC fast charger/ 50 kW DC fast charger/ 100 kW charger have been taken as 72 V and 500 V respectively
- It is assumed that harmonic injection by SRTPV in the distribution network is balanced
- The consumer load has been divided in the ratio of DT to the sanctioned load in kW to the number of service connections
- The power factor for the F03 Ittamadu feeder has been assumed as 90%
- The efficiency for SRTPV inverters (5 to 10 kW) has been assumed as 98.6%; for commercial PV inverters it is taken as 98.4%
- The harmonic injections spectrum for EVCS has been assumed to be same as that of the harmonics measured at EVCS at corporate office of BESCOM (data received from BESCOM)

5.4 Scenarios Considered for the System Studies

The system studies have been conducted for following Scenarios:

Case 1: 11 kV feeder without EVSE and without SRTPV

Case 2: 11 kV feeder connected with 44 kW EVSE load for the year 2020

Case 3: 11 kV feeder with a load growth of 6% per year connected with 144 kW of EVSE load and 100 kW of SRTPV for the year 2022

Case 4: 11 kV feeder with a load growth of 6% per year connected with 344 kW of EVSE load and 500 kW of SRTPV for the year 2025

Although BESCOM intends to promote solar rooftop PV (SRTPV) in its service area, the actual installation of the SRTPV depends on the building owner, price of PV systems, subsidies etc[10]. In the absence of credible data on how much SRTPV will be installed on the 12 selected feeders by 2022 and 2025, ISGF has assumed 100 kW of SRTPV by 2022 and 500 kW by 2025 on these feeders for modelling studies.

It was found that injection of energy on to the feeders from the SRTPV systems will improve the voltage profile of the feeder when EV loads are applied; but a higher share of SRTPV injection will increase harmonics as well. For installation of SRTPV or EVCS no specific regulatory interventions are required.

5.5 Study Scenarios for the Feeders

The distribution network scenario for five years starting from the year 2020 with a load growth of 6% per annum over the conventional network and the impact of the EVCS on the network along with expected SRTPV. The 2020 Scenario was analysed without the EVCS (case 1) and with EVCS having 44 kW of EVSE load (case 2). For 2022 Scenario, a new EVCS with 100 kW EVSE load and 100 kW distributed SRTPV on different buildings is considered. For 2025 Scenario, 344 kW EVSE load at 3 locations (44 kW + 100 kW + 200 kW) and 500 kW of SRTPV on different buildings connected to the feeder have been considered. New distribution transformers have been considered for the new EVCS.

The details of load flow study and analysis of F03 Ittamadu feeder emanating from the 66/11 kV Arehally substation in Bengaluru City are described in Table 5-4.

Table 5-4: Study summary for F03 Ittamadu feeder

Parameters	2020 (Without EVSE)	2020 (With EVSE)	2022 (With EVSE and SRTPV)	2025 (With EVSE and SRTPV)
Peak load (kW) on Ittamadu feeder	2730	2730	3067.4	3653.4
Total source dispatch (kW)	2715	2761	3003	3316
Total load (kW) (Including EV-AC load and 6 % increment/year)	2369	2372	2599	3039
Total loss (kW)	346.45	349.83	404.29	447.26
Total EV load (kW)	0	44	144	344
Total PV generation (kW)	0	0	100	500
Total source (kVAR)	1313	1327	1486	1698
Total loss (kVAR)	777.07	790.16	897.17	1009.92
Total No. of sections in Ittamadu	2692	2697	2702	2706
No. of overloaded elements	52	53	58	64
No. of under-voltage sections	727	727	793	927

10 DSM Department of BESCOM do not have data related to what quantities of SRTPV will be installed on the selected 12 feeders by 2022 or 2025.

The details of load flow study and analysis of F07 HAL feeder emanating from the 66/11 kV HAL substation in Bengaluru City are described in Table 5-5.

Table 5-5: Study summary for F07 HAL feeder

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total source dispatch (kW)	1871	1917	2150	2357
Total load (kW) (including EV-AC load and 6 % increment/year)	1791	1794	2026	2410
Total loss (kW)	80	83	95	117
Total EV load (kW)	0	44	144	344
Total PV generation (kW)	0	0	100	500
Total source (kVAR)	896	910	1012	1197
Total loss (kVAR)	407	421	456	531
Total No. of sections in HAL	1511	1516	1521	1525
No. of overloaded elements	26	26	26	27
No. of under-voltage sections	340	341	340	350

The details of load flow study and analysis of F08 ITI Aux feeder emanating from the 66/11 kV Hoody substation in Bengaluru City are described in Table 5-6.

Table 5-6: Study summary for F08 ITI Aux feeder

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total source dispatch (kW)	5274	5322	5974	6925
Total load (kW) (Including EV-AC Load and 6 % increment/year)	4877	4880	5465	6471
Total loss (kW)	397	402	478	624
Total EV load (kW)	0	44	144	344
Total PV generation (kW)	0	0	100	500
Total source (kVAR)	2459	2485	2777	3297
Total loss (kVAR)	1268	1293	1440	1712

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total No. of sections in ITI Aux	3730	3734	3738	3741
No. of overloaded elements	111	111	126	123
No. of under-voltage sections	1189	1193	1091	793

The details of load flow study and analysis of F19 KIADB feeder emanating from the 66/11 kV Brindavana substation in Bengaluru City are described in Table 5-7.

Table 5-7: Study summary for F19 KIADB feeder

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total source dispatch (kW)	549	595	670	600
Total load (kW) (Including EV-AC load and 6 % increment/year)	540	543	619	736
Total loss (kW)	10	13	20	34
Total EV load (kW)	0	44	144	344
Total PV generation (kW)	0	0	100	500
Total source (kVAR)	263	277	312	382
Total loss (kVAR)	227	241	268	329
Total No. of sections in Kiadb	96	100	104	107
No. of overloaded elements	0	0	2	4
No. of under-voltage sections	0	0	0	0

The details of load flow study and analysis of F01 Vidhana Soudha feeder emanating from the 66/11 kV C- Station substation in Bengaluru City are described in Table 5-8.

Table 5-8: Study summary for F01 Vidhana Soudha feeder

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total source dispatch (kW)	3758	3814	4267	4411
Total load (kW) (Including EV-AC load and 6 % increment/year)	3368	3381	3793	4044
Total loss (kW)	390	393	444	537

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total EV load (kW)	0	44	144	344
Total PV generation (kW)	0	0	100	500
Total source (kVAR)	1833	1847	2084	2225
Total loss (kVAR)	556	566	643	686
Total No. of sections in Kiadb	602	607	613	618
No. of overloaded elements	42	42	44	38
No. of under-voltage sections	358	358	361	359

The details of load flow study and analysis of F08 Byatha feeder emanating from the 66/11 kV KHB substation in Bengaluru City are described in Table 5-9.

Table 5-9: Study summary for F08 Byatha feeder

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total source dispatch (kW)	5556	5602	6207	7018
Total load (kW) (Including EV-AC load and 6 % increment/year)	4838	4841	5354	6182
Total loss (kW)	717	721	823	1005
Total EV load (kW)	0	44	144	344
Total PV generation (kW)	0	0	100	500
Total source (kVAR)	6185	2733	3026	3532
Total loss (kVAR)	1533	1548	1712	2001
Total No. of sections in Kiadb	950	955	960	964
No. of overloaded elements	149	149	152	164
No. of under-voltage sections	570	570	574	575

The details of load flow study and analysis of F04 14th Cross RMU feeder emanating from the 66/11 kV Amarjyothi substation in Bengaluru City are described in Table 5-10.

Table 5-10: Study summary for F04 14th Cross RMU feeder

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and RTPV)	2025 (With EV & RTPV)
Total source dispatch (kW)	2926	2972	3339	3816
Total load (kW) (Including EV-AC load and 6 % increment/year)	2780	2783	3142	3784

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total loss (kW)	146	149	167	202
Total EV load (kW)	0	44	144	344
Total PV generation (kW)	0	0	100	500
Total source (kVAR)	1305	1319	1486	1798
Total loss (kVAR)	421	434	486	593
Total No. of sections in Kiadb	650	655	660	664
No. of overloaded elements	34	34	39	41
No. of under-voltage sections	260	260	450	445

The details of load flow study and analysis of F07 Subbaihanpalya feeder emanating from the 66/11 kV Banaswadi substation in Bengaluru City are described in Table 5-11.

Table 5-11: Study summary for F07 Subbaihanpalya feeder

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total source dispatch (kW)	4319	4366	4908	5649
Total load (kW) (Including EV-AC load and 6 % increment/year)	4166	4169	4694	5588
Total loss (kW)	153	157	184	231
Total EV load (kW)	0	44	144	344
Total PV generation (kW)	0	0	100	500
Total source (kVAR)	2096	2122	2304	2617
Total loss (kVAR)	1185	1210	1274	1388
Total No. of sections in Kiadb	6565	6569	6573	6575
No. of overloaded elements	33	39	63	84
No. of under-voltage sections	733	733	749	819

The details of load flow study and analysis of F25 BSK feeder emanating from the 66/11 kV Banashankari substation in Bengaluru City are described in Table 5-12.

Table 5-12: Study summary for F25 BSK feeder

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total source dispatch (kW)	3683	3730	4219	4830
Total load (kW) (Including EV-AC load and 6 % increment/year)	3529	3532	3995	4756
Total loss (kW)	154	158	194	244
Total EV load (kW)	0	44	144	344

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total PV generation (kW)	0	0	100	500
Total source (kVAR)	1804	1818	2013	2330
Total loss (kVAR)	873	887	960	1072
Total No. of sections in Kiadb	3480	3484	3489	3492
No. of overloaded elements	45	45	52	60
No. of under-voltage sections	2594	2594	2904	3263

The details of load flow study and analysis of F03 HSR feeder emanating from the 66/11 kV HSR layout substation in Bengaluru City are described in Table 5-13.

Table 5-13: Study summary for F03 HSR feeder

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total source dispatch (kW)	3109	3155	3548	4022
Total load (kW) (Including EV-AC load and 6 % increment/year)	3041	3044	3430	4083
Total loss (kW)	68	71	87	109
Total EV load (kW)	0	44	144	344
Total PV generation (kW)	0	0	100	500
Total source (kVAR)	1508	1522	1693	1962
Total loss (kVAR)	604	618	652	723
Total No. of sections in Kiadb	2417	2422	2427	2431
No. of overloaded elements	5	5	5	6
No. of under-voltage sections	50	50	56	86

The details of load flow study and analysis of F07 MTK feeder emanating from the 66/11 kV Mathikere substation in Bengaluru City are described in Table 5-14.

Table 5-14: Study summary for F07 MTK feeder

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total source dispatch (kW)	3907	3953	4448	5109
Total load (kW) (Including EV-AC load and 6 % increment/year)	3785	3788	4266	5078
Total loss (kW)	123	125	152	201
Total EV load (kW)	0	44	144	344

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total PV generation (kW)	0	0	100	500
Total source (kVAR)	1870	1884	2086	2447
Total loss (kVAR)	734	748	805	920
Total No. of sections in Kiadb	4799	4803	4808	4813
No. of overloaded elements	13	13	26	51
No. of under-voltage sections	1532	1532	2040	2887

The details of load flow study and analysis of F01 SJW feeder emanating from the 66/11 kV SJW substation in Bengaluru City are described in Table 5-15.

Table 5-15: Study summary for F01 SJW feeder

Objective	2020 (W/O EV)	2020 (With EV)	2022 (With EV and SRTPV)	2025 (With EV and SRTPV)
Total source dispatch (kW)	5730	5776	6445	7608
Total load (kW) (Including EV-AC load and 6 % increment/year)	5134	5137	5798	7143
Total loss (kW)	596	599	617	635
Total EV load (kW)	0	44	144	344
Total PV generation (kW)	0	0	100	500
Total source (kVAR)	2340	2355	2612	3089
Total loss (kVAR)	831	845	904	971
Total No. of sections in Kiadb	1668	1672	1678	1679
No. of overloaded elements	227	227	234	250
No. of under-voltage sections	933	933	902	891

5.6 Summary of the Study Results of the 12 Feeders

List of the 12 feeders and the scenarios considered for modelling studies are given in table 5-16.

Table 5-16: Summary of load flow study conducted and scenarios simulated

List and Characteristics of 12 Feeders Studied							2020			2022			2025		
Sl No	Substation Name	Feeder Name	Line Length (km)			Number of DTs	Peak Load (MW)	EVSE Load (kW)	SRTPV Load (kW)	Peak Load (MW)	EVSE Load (kW)	SRT-PV Load (kW)	Peak Load (MW)	EVSE Load (kW)	SRT-PV Load (kW)
			Over-head	Under ground	Total Length										
1	66/11 kV Arehally	F03 Ittamadu	10.1	18.5	28.6	22	2.73	44	0	3.067	144	100	3.65	344	500
2	66/11 kV HAL	F07 HAL	4.3	23.8	28.1	25	1.88	44	0	2.11	144	100	2.52	344	500
3	66/11 kV Hoody	F08 ITI AUX	13.99	50.5	64.49	61	5.29	44	0	5.95	144	100	7.08	344	500
4	66/11 kV Brindavana	F19 KIADB	0.4	2.09	2.49	9	0.55	44	0	0.62	144	100	0.74	344	500
5	66/11 kV Vidhana Soudha	F01 C-Station	1.716	15.99	17.706	11	4.99	44	0	5.61	144	100	668	344	500
6	66/11 kV Amarjyothi	F04 Cross-RMU	1.8	16.5	18.3	12	2.72	44	0	3.06	144	100	3.64	344	500
7	66/11 kV Banaswadi	F07 Subbaihanpalya	35.5	57.7	93.2	140	4.32	44	0	4.86	144	100	5.78	344	500
8	66/11 kV Banashankari	F25 BSK	16.26	34.2	50.46	55	3.69	44	0	4.15	144	100	4.94	344	500
9	220/11 kV HSR Layout	F03 HSR	15.6	18.7	34.3	64	3.11	44	0	3.50	144	100	4.16	344	500
10	66/11 kV KHB	F08 Byatha	10.4	9.92	20.32	37	5.56	44	0	6.25	144	100	7.44	344	500
11	66/11 kV Mathikere	F07 MTK	20	44.5	64.5	59	3.81	44	0	4.28	144	100	5.10	344	500
12	66/11 kV St. Johnswood	F01 SJW	9.35	18.3	27.65	66	5.96	44	0	6.70	144	100	7.97	344	500

5.7 Impact of EVCS and Mitigation Measures

Table 5-17: Mitigation measures recommended for 11 kV F03 Ittamadu feeder

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2020	44 kW EV load	53	727	Current harmonics	Yes	1. TC17 GANAPATHI TEMPLE: New DT of 1000 kVA 2. TC130 NEAR ANJANEYA TEMPLE: New DT of 100 kVA 3. TC18 ITTAMADU: New DT of 150 kVA 4. TC 22 NEAR OMSHAKTI TEMPLE: New DT of 50 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 20 kVAR; along with a C-type filter rated at 100 kVAR tuned at 3rd order harmonic frequency at EVCS-1.	Yes, with higher withstand capacity.
2022	144 kW EV load and 100 kW SRTPV	58	793	Current harmonics	Yes	1. TC17 GANAPATHI TEMPLE: New DT of 1200 kVA 2. TC130 NEAR ANJANEYA TEMPLE: New DT of 100 kVA 3. TC18 ITTAMADU: New DT of 150 kVA 4. TC22 NEAR OMSHAKTI TEMPLE: New DT of 63 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 30 kVAR for EVCS-1&2; along with a C-type filter rated at 100 kVAR for EVCS-1 and 150 kVAR for EVCS-2 tuned at 3rd order harmonic frequency.	Yes, with higher withstand capacity.
2025	344 kW EV load and 500 kW SRTPV	64	927	Current harmonics	Yes	1. TC17 GANAPATHI TEMPLE: New DT of 1500 kVA 2. TC130 NEAR ANJANEYA TEMPLE: New DT of 100 kVA 3. TC18 ITTAMADU: New DT of 150 kVA 4. TC22 NEAR OMSHAKTI TEMPLE: New DT of 100 kVA 5. TC 21 ANJANEYA: New DT of 50 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 30 kVAR for EVCS-1&2; along with a C-type filter rated at 100 kVAR for EVCS-1 and 150 kVAR for EVCS-2 tuned at 3rd order harmonic frequency. For EVCS-3, double tuned filter of 50 kVAR and 100 kVAR C-type filter.	Yes, with higher withstand capacity.

Table 5-18: Mitigation measures recommended for 11 kV F07 HAL feeder

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2020	44 kW EV load	26	341	Current harmonics	Yes	1. DTC 04 KATTA TC: New DT of 250 kVA 2. TC 03 RAJESHWARY 2ND T.C (FOOD PALACE): New DT of 250 kVA 3. TC 83 VENKATESH T.C (JUBLI MRIDIAN): New DT of 315 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 20 kVAR; along with a C-type filter rated at 150 kVAR tuned at 3rd order harmonic frequency at EVCS-1.	Yes, with higher withstand capacity.
2022	144 kW EV load and 100 kW SRTPV	26	340	Current harmonics	Yes	1. DTC 04 KATTA TC: New DT of 125 kVA 2. TC 03 RAJESHWARY 2ND T.C (FOOD PALACE): New DT of 300 kVA 3. TC83 VENKATESH T.C (JUBLI MRIDIAN): New DT of 315 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 20 kVAR; along with a C-type filter rated at 150 kVAR tuned at 3rd order harmonic frequency at EVCS-1.	Yes, with higher withstand capacity.
2025	344 kW EV load and 500 kW SRTPV	27	350	Current harmonics	Yes	1. DTC 04 KATTA TC: New DT of 125 kVA 2. TC 03 RAJESHWARY 2ND T.C (FOOD PALACE): New DT of 300 kVA 3. TC83 VENKATESH T.C (JUBLI MRIDIAN): New DT of 315 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 30 kVAR for EVCS-1&2; along with a C-type filter rated at 150 kVAR for EVCS-1 and EVCS-2 tuned at 3rd order harmonic frequency.	Yes, with higher withstand capacity.

Table 5-19: Mitigation measures recommended for 11 kV F08 ITI AUX feeder

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/ No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2020	44 kW EV load	111	1193	Current harmonics	Yes	1. TC39 SINGAYANPALYA: New DT of 2*500 kVA 2. TC01 HDY: New DT of 100 kVA 3. TC09 PRECION TELICOM: New DT of 150 kVA 4. TC17 SHRI RAM INDUSTRY: New DT of 2*700 kVA 5. TC 34 SHYLENDRA: New DT of 63 kVA 6. TC35 HOODY: New DT of 250 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 20 kVAR; along with a C-type rated at 100 kVAR tuned at 3rd order harmonic frequency at EVCS-1.	Yes, with higher withstand capacity.
2022	144 kW EV load and 100 kW SRTPV	126	1091	Current harmonics	Yes	1. TC39 SINGAYANPALYA: New DT of 2*500 kVA 2. TC01 HDY: New DT of 100 kVA 3. TC09 PRECION TELICOM: New DT of 200 kVA 4. TC17 SHRI RAM INDUSTRY: New DT of 3*630 kVA 5. TC34 SHYLENDRA: New DT of 100 kVA 6. TC35 HOODY: New DT of 200 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 30 kVAR for EVCS-1&2; along with a C-type rated in the range of 100-150 kVAR for EVCS-1&2 tuned at 3rd order harmonic frequency.	Yes, with higher withstand capacity.
2025	344 kW EV load and 500 kW SRTPV	123	793	Current harmonics	Yes	1. TC30 GARUDACHAR: New DT of 125 kVA 2. TC39 SINGAYANPALYA: New DT of 3*600 kVA 3. TC01 HDY: New DT of 50 kVA 4. TC09 PRECION TELICOM: New DT of 250 kVA 5. TC17 SHRI RAM INDUSTRY: New DT of 3*800 kVA 6. TC34 SHYLENDRA: New DT of 100 kVA 7. TC35 HOODY: New DT of 125 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 30 kVAR for EVCS-1&2; along with a C-type filter rated in the range of 100-150 kVAR for EVCS-1&2 at 3rd order harmonic frequency. For EVCS-3, double tuned filter of 50 kVAR and 100 kVAR C-type filter.	Yes, with higher withstand capacity.

Table 5-20: Mitigation measures recommended for 11 kV F19 Kiadb feeder

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2020	44 kW EV load	0	0	Current harmonics	Yes	Not required.	Double tuned filter for 5th and 7th harmonic with capacity rated at 20 kVAR; along with a C-type filter rated at 30 kVAR tuned at 3rd order harmonic frequency at EVCS-1.	Yes, with higher withstand capacity.
2022	144 kW EV load and 100 kW SRTPV	2	0	Current harmonics	Yes	Not required.	Double tuned filter for 5th and 7th harmonic with capacity rated at 25 kVAR for EVCS-1&2; along with a C-type rated at 50 kVAR for EVCS-1&2 tuned at 3rd order harmonic frequency.	Yes, with higher withstand capacity.
2025	344 kW EV load and 500 kW SRTPV	4	0	Current harmonics	Yes	Not required.	Double tuned filter for 5th and 7th harmonic with capacity rated at 20 kVAR for EVCS-1 and 10 kVAR at EVCS-2; along with a C-type rated at 100 kVAR for EVCS-1&2 at 3rd order harmonic frequency. For EVCS-3, double tuned filter of 50 kVAR and 30 kVAR C-type filter.	Yes, with higher withstand capacity.

Table 5-21: Mitigation measures recommended for 11 kV F01 C-Station feeder

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2020	44 kW EV load	42	358	Current harmonics	Yes	1. TC15 RAMANJANEYA CANTEEN: New DT of 630 kVA 2. TC127 NOORULA: New DT of 125 kVA 3. TC 142 BROAD WAY ROAD: New DT of 1150 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 25 kVA at EVCS-1.	Yes, with higher withstand capacity.
2022	144 kW EV load and 100 kW SRTPV	44	361	Current harmonics	Yes	1. TC15 RAMANJANEYA CANTEEN: New DT of 750 kVA 2. TC 127 NOORULA: New DT of 160 kVA 3. TC 142 BROAD WAY ROAD: New DT of 1150 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 25 kVAR for EVCS-1 and 10 kVAR at EVCS-2; along with a C-type filter rated at 100 kVAR for EVCS-2 tuned at 3rd order harmonic frequency.	Yes, with higher withstand capacity.

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2025	344 kW EV load and 500 kW SRTPV	38	359	Current harmonics	Yes	1. TC15 RAMANJANEYA CANTEEN: New DT of 950 kVA 2. TC127 NOORULA: New DT of 250 kVA 3. TC 142 BROAD WAY ROAD: New DT of 1300 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 25 kVAR for EVCS-1 and 10 kVAR at EVCS-2; along with a C-type rated at 100 kVAR for EVCS-2 at 3rd order harmonic frequency. For EVCS-3, double tuned filter of 50 kVAR and 75 kVAR C-type filter.	Yes, with higher withstand capacity.

Table 5-22: Mitigation measures recommended for 11 kV F08 Byatha feeder

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/ No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2020	44 kW EV load	149	570	Current harmonics	Yes	1. TC138 OPP KHB 66 kV/11 kV SUB STATION: New DT of 250 kVA to 300 kVA 2. TC52 SANTHUR SERVICE STATION GANDHI NAGAR KHB: New DT of 1500 kVA 3. TC384 POST OFFICE NEHERU NAGAR TC: New DT of 630 kVA 4. TC124 BUS STOP POST OFFICE YNK: New DT of 25 kVA 5. TC56 SHUSHRUSHA NURSHING HOME: New DT of 900 kVA 6. TC258 KENDRIYA VIHAR BHAVAN: New DT of 500 kVA to 1000 kVA 7. TC257 KENDRIYA VIHAR BHAVAN: New DT of 500 kVA to 1000 kVA 8. TC73 BAZAR ROAD: New DT of 250 kVA 9. TC49 NEAR ASWINI HOSPITAL: New DT of 160 kVA 10. TC135 OPP KHB 66 kV/11 kV SUB STATION: New DT of 250 kVA to 350 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 15 kVAR; along with a C-type filter rated at 30 kVAR tuned at 3rd order harmonic frequency at EVCS-1.	Yes, with higher withstand capacity.

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/ No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2022	144 kW EV load and 100 kW SRTPV	152	574	Current harmonics	Yes	1. TC138 OPP KHB 66 kV/11 kV SUB STATION: New DT of 250 kVA to 400 kVA 2. TC52 SANTHUR SERVICE STATION GANDHI NAGAR KHB: New DT of 1550 kVA 3. TC384 POST OFFICE NEHERU NAGAR TC: New DT of 700 kVA 4. TC124 BUS STOP POST OFFICE YNK: New DT of 50 kVA 5. TC56 SHUSHRUSHA NURSHING HOME: New DT of 1000 kVA 6. TC258 KENDRIYA VIHAR BHAVAN: New DT of 500 kVA to 1150 kVA 7. TC257 KENDRIYA VIHAR BHAVAN: New DT of 500 kVA to 1000 kVA 8. TC73 BAZAR ROAD: New DT of 315 kVA 9. TC49 NEAR ASWINI HOSPITAL: New DT of 160 kVA 10. TC135 OPP KHB 66 kV/11 kV SUB STATION: New DT of 250 kVA to 400 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 25 kVAR for EVCS-1&2; along with a C-type filter rated at 100 kVAR for EVCS-1&2 tuned at 3rd order harmonic frequency.	Yes, with higher withstand capacity.
2025	344 kW EV load and 500 kW SRTPV	164	575	Current harmonics	Yes	1. TC138 OPP KHB 66 kV/11 kV SUB STATION: New DT of 250 kVA to 400 kVA 2. TC52 SANTHUR SERVICE STATION GANDHI NAGAR KHB: New DT of 1550 kVA 3. TC384 POST OFFICE NEHERU NAGAR TC: New DT of 700 kVA 4. TC124 BUS STOP POST OFFICE YNK: New DT of 50 kVA 5. TC56 SHUSHRUSHA NURSHING HOME: New DT of 1000 kVA 6. TC258 KENDRIYA VIHAR BHAVAN: New DT of 500 kVA to 1150 kVA 7. TC257 KENDRIYA VIHAR BHAVAN: New DT of 500 kVA to 1000 kVA 8. TC73 BAZAR ROAD: New DT of 315 kVA 9. TC49 NEAR ASWINI HOSPITAL: New DT of 160 kVA 10. TC135 OPP KHB 66 kV/11 kV SUB STATION: New DT of 250 kVA to 400 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 20 kVAR for EVCS-1 and 10 kVAR at EVCS-2; along with a C-type rated at 100 kVAR for EVCS-1&2 at 3rd order harmonic frequency. For EVCS-3, double tuned filter of 75 kVAR and 30 kVAR C-type filter.	Yes, with higher withstand capacity.

Table 5-23: Mitigation measures recommended for 11 kV F04 14th Cross RMU feeder

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/ No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2020	44 kW EV load	34	260	Current harmonics	Yes	1. 14th Cross 1st TC: New DT of 250 kVA 2. 14th Cross 2nd TC: New DT of 700 kVA 3. AK Colony Domlur: New DT of 150 kVA 4. Natasa Apartment 1st TC: New DT of 500 kVA to 1200 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 20 kVAR; along with a C-type filter rated at 30 kVAR tuned at 3rd order harmonic frequency at EVCS-1.	Yes, with higher withstand capacity.
2022	144 kW EV load and 100 kW SRTPV	39	450	Current harmonics	Yes	1. 14th Cross 1st TC: New DT of 250 kVA 2. 14th Cross 2nd TC: New DT of 800 kVA 3. AK Colony Domlur: New DT of 125 kVA 4. Natasa Apartment 1st TC: New DT of 500 kVA to 1500 kVA	Double tuned filter for 5th an 7th Harmonic with capacity rated at 30 kVAR for EVCS-1 and 10 kVAR at EVCS-2; along with a C-type filter rated at 100 kVAR for EVCS-1&2 tuned at 3rd order harmonic frequency.	Yes, with higher withstand capacity.
2025	344 kW EV load and 500 kW SRTPV	41	445	Current harmonics	Yes	1. 14th Cross 1st TC: New DT of 160 kVA 2. 14th Cross 2nd TC: New DT of 1000 kVA 3. AK Colony Domlur: New DT of 125 kVA 4. Natasa Apartment 1st TC: New DT of 500 kVA to 1700 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 25 kVAR for EVCS-1&2; along with a C-type rated at 30 kVAR for EVCS-1 and 100 kVAR at EVCS-2 at 3rd order harmonic frequency. For EVCS-3, double tuned filter of 75 kVAR and 30 kVAR C-type filter.	Yes, with higher withstand capacity.

Table 5-24: Mitigation measures recommended for 11 kV F07 Subhaihanpalya feeder

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/ No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2020	44 kW EV load	39	733	Current harmonics	Yes	1. DT PARVEEZ SHAKOOR SUB STATION: New DT of 63 kVA to 125 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated in the range of 20-30 kVAR; along with a C-type rated at 100 kVAR tuned at 3rd order harmonic frequency at EVCS-1.	Yes, with higher withstand capacity.
2022	144 kW EV load and 100 kW SRTPV	63	749	Current harmonics	Yes	1. DT PARVEEZ SHAKOOR SUB STATION: New DT of 63 kVA to 125 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 30 kVAR for EVCS-1&2; along with a C-type rated in the range of 100kVAR - 150kVAR for EVCS-1&2 tuned at 3rd order harmonic frequency.	Yes, with higher withstand capacity.
2025	344 kW EV load and 500 kW SRTPV	84	819	Current harmonics	Yes	1. DT PARVEEZ SHAKOOR SUB STATION: New DT of 63 kVA to 200 kVA 2. DT SAYAD ABDUL GAFFER: New DT of 100 kVA to 150 kVA 3. DT SUB REGISTER OFFICE: New DT of 100 kVA to 150 kVA 4. DT USHA B JAGNANI-1ST BLOCK: New DT of 100 kVA to 150 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 30 kVAR for EVCS-1&2; along with a C-type rated in the range of 100-150 kVAR for EVCS-1&2 at 3rd order harmonic frequency. For EVCS-3, double tuned filter of in the range of 50 kVAR-75 kVAR and 100 kVAR C-type filter.	Yes, with higher withstand capacity.

Table 5-25: Mitigation measures recommended for 11 kV F25 BSK feeder

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/ No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2020	44 kW EV load	38	911	Current harmonics	Yes	1. DT Shaneshwara Temple: New DT of 100 kVA 2. DT BR Pura 58 Bus Stop: New DT of 250 kVA 3. DT Sharada School TC E&I: New DT of 300 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated in the range of 20 kVAR-30 kVAR; along with a C-type filter rated at 100 kVAR tuned at 3rd order harmonic frequency at EVCS-1.	Yes, with higher withstand capacity.
2022	144 kW EV load and 100 kW SRTPV	43	1016	Current harmonics	Yes	1. DT Shaneshwara Temple: New DT of 150 kVA 2. DT BR Pura 58 Bus Stop: New DT of 300 kVA 3. DT Sharada School TC E&I: New DT of 300 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 30 kVAR for EVCS-1&2; along with a C-type rated in the range of 100 kVAR-150 kVAR for EVCS-1&2 tuned at 3rd order harmonic frequency.	Yes, with higher withstand capacity.
2025	344 kW EV load and 500 kW SRTPV	45	1136	Current harmonics	Yes	1. DT- Shaneshwara Temple: New DT of 150kVA 2. DT-BR Pura 58 Bus Stop: New DT of 350kVA 3. DT- Sharada School-TC E&I: New DT of 315kVA 4. DT-B. Pura School: New DT of 160kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 30 kVAR for EVCS-1&2; along with a C-type rated in the range of 100kVAR-150kVAR for EVCS-1&2 at 3rd order harmonic frequency. For EVCS-3, double tuned filter of in the range of 50 kVAR-75 kVAR and 100 kVAR C-type filter.	Yes, with higher withstand capacity.

Table 5-26: Mitigation measures recommended for 11 kV F03 HSR feeder

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/ No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2020	44 kW EV load	5	50	Current harmonics	Yes	1. DT 20TH CROSS ROAD: New DT of 63 kVA 2. DT MLA KUMARA SWAMY HSR 1ST SECTOR OPP TC19: New DT of 63 kVA to 250 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 25 kVAR at EVCS-1.	Yes, with higher withstand capacity.
2022	144 kW EV load and 100 kW SRTPV	5	56	Current harmonics	Yes	1. DT 20TH CROSS ROAD: New DT of 100 kVA 2. DT MLA KUMARA SWAMY HSR 1ST SECTOR OPP TC19: New DT of 63 kVA to 315 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 25 kVAR; along with a 10 kVAR C-type filter at EVCS-1&2.	Yes, with higher withstand capacity.
2025	344 kW EV load and 500 kW SRTPV	6	86	Current harmonics	Yes	1. DT 20TH CROSS ROAD: New DT of 160 kVA 2. DT MLA KUMARA SWAMY HSR 1ST SECTOR OPP TC19: 63 kVA to 450 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 25 kVAR for EVCS-1 and 20 kVAR at EVCS-2; along with a C-type filter rated at 10 kVAR for EVCS-1 & 2, tuned at 3rd order harmonic frequency. For EVCS-3, double tuned filter of 75 kVAR and 30 kVAR C-type filter.	Yes, with higher withstand capacity.

Table 5-27: Mitigation measures recommended for 11 kV F07 MTK feeder

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/ No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2020	44 kW EV load	12	549	Current harmonics	Yes	1. DT Sub Division Office: New DT of 200 kVA 2. DT Venkateshwara School: New DT of 63 kVA 3. DT IV Main Road AK Colony: New DT of 125 kVA 4. DT Near Bus Stop Mathikere: New DT of 125 kVA	Double tuned filter for 5^{th} and 7^{th} harmonic with capacity rated in the range of 20 kVAR-30 kVAR; along with a C-type rated at 100 kVAR tuned at 3rd order harmonic frequency at EVCS-1.	Yes, with higher withstand capacity.

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/ No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2022	144 kW EV load and 100 kW SRTPV	24	726	Current harmonics	Yes	1. DT Sub Division Office: New DT of 200 kVA 2. DT Venkateshwara School: New DT of 63 kVA 3. DT IV Main Road AK Colony: New DT of 25 kVA 4. DT Near Bus Stop Mathikere: New DT of 125 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 30 kVAR for EVCS-1&2; along with a C-type rated in the range of 100 kVAR-150 kVAR for EVCS-1&2 tuned at 3rd order harmonic frequency.	Yes, with higher withstand capacity.
2025	344 kW EV load and 500 kW SRTPV	48	1029	Current harmonics	Yes	1. DT Sub Division Office: New DT of 250 kVA 2. DT Venkateshwara School: New DT of 63 kVA 3. DT IV Main Road AK Colony: New DT of 125 kVA 4. DT Near Bus Stop Mathikere: New DT of 200 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 30 kVAR for EVCS-1&2; along with a C-type rated in the range of 100 kVAR-150 kVAR for EVCS-1&2 at 3rd order harmonic frequency. For EVCS-3, double tuned filter of in the range of 50 kVAR-75 kVAR and 100 kVAR C-type filter.	Yes, with higher withstand capacity.

Table 5-28: Mitigation measures recommended for 11 kV F01 SJW feeder

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/ No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2020	44 kW EV load	227	933	Current harmonics	Yes	1. DT 11th Main MICO Layout: New DT of 200 kVA 2. DT 15th Main MICO Layout: New DT of 250 kVA 3. DT 20th Main Opp Ladies and Vimarsa Residency: New DT of 125 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 25 kVAR at EVCS-1.	Yes, with higher withstand capacity.
2022	144 kW EV load and 100 kW SRTPV	234	902	Current harmonics	Yes	1. DT 11th Main MICO Layout: New DT of 250 kVA 2. DT 15th Main MICO Layout: New DT of 250 kVA 3. DT 20th Main Opp Ladies and Vimarsa Residency: New DT of 125 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 25 kVAR; along with a 10 kVAR C-type filter at EVCS-1&2.	Yes, with higher withstand capacity.

Year	EV and SRTPV	Fault Scenarios				Mitigation Measures Recommended		
		Under Voltage (Volts)	Overload (Locations)	Current Harmonics/ Voltage Harmonics	Cable Fault (Yes/ No)	Distribution Transformers to be Upgraded	Harmonics Mitigation	Cable Upgrade
2025	344 kW EV load and 500 kW SRTPV	250	891	Current harmonics	Yes	1. DT 11th Main MICO Layout: New DT of 250 kVA 2. DT 15th Main MICO Layout: New DT of 300 kVA 3. DT 20th Main Opp Ladies and Vimarsa Residency: New of DT 160 kVA	Double tuned filter for 5th and 7th harmonic with capacity rated at 25 kVAR for EVCS-1 and 20 kVAR at EVCS-2; along with a C-type filter rated at 10 kVAR for EVCS-1&2, tuned at 3rd order harmonic frequency. For EVCS-3, double tuned filter of 75 kVAR and 30 kVAR C-type filter.	Yes, with higher withstand capacity.

Note: The load flow study results indicated the exact size of distribution transformer (DT) capacity to be added to the feeder for the scenario modelled. But it is recommended to install all new DTs of a minimum of 100 kVA or above. Similarly, the size of filters indicated in the table above are also from the load flow model. But it is recommended to install the next larger commercially available size of the filters.

5.8 Conclusion

Home charging of EVs typically happens at night when other electrical loads in a house are low. Hence, home charging may be encouraged with a reduced tariff between 11 pm - 5 am. Home charging may not have a huge impact on the grid, though several EVs are charged at some locations that could inject harmonics beyond the acceptable limits. It is recommended to install Power Quality Meters (PQM) on feeders that supply to high-income communities and Government Housing complexes where several EVs may be charged at night. PQM readings may be monitored and if harmonics are beyond acceptable limits as per IEEE-519:2014. Karnataka Government's EV Policy envisages 50% of all vehicles in Bengaluru to be EVs by 2030, which is approximately 1.2 million vehicles. The details are given in Table 4-1.

Actual EV stock in 2030, its total load on the grid and energy sales depends on several factors. EV uptake depends on EV price, battery performance, government policies, availability and choice of different EV models, etc. The battery size in EVs that may be launched in 2022 or 2025 is not public information; neither EV manufacturers share this with others. And which model of EVs will be majorly bought in Bengaluru is yet another matter. The report presented the operational impacts of EV load on the grid in Section 4.4 and the analysis and mitigation measures are given in Section 5.6.

Assessing the expected EV load on the grid in 2030 and consequent upgrade of transmission grid are not in the scope of this study. The detailed load flow analysis and single line diagram of 12 feeders has been given in Annexure – IV.

5.9 Findings and Recommendations

The study's key finding is that the increment in EV charging stations beyond the network's existing capacity would have increased power losses and overloading situations compared to without the charging stations.

The feeders in the current scenario was found overloaded and struggling with multiple under-voltage LT lines. For EVCS integration on the Ittamandu feeder, DT augmentation form 63 kVA to 100 kVA was suggested for a planned loading of 80%. For the rest of the feeders, HAL, ITI Aux and KIADB, C-Station, Byatha, Cross RMU, Subbhaimalya, BSK, and HSR, the EVCS transformer capacity was found sufficient to deal with the planned load. The adjacent connecting cables to EVCS were running fine within the acceptable loading limits. However, the power loss of the distribution network after the integration of charging stations was high compared to normal load conditions. Electric demand of EV charging stations can be served with the addition of local SRTPVs to the grid, it would also help in demand-side management of the conventional grid. The SRTPV generation helped reduce the voltage drop, especially when connected to the tail end of feeders. It also helped compensate for the load fetched from the grid source, which resulted in lesser-overloaded lines in certain scenarios.

However, with the increased installations of EVCS and SRTPV, the distribution network experiences harmonic distortion majorly near to the point of connection. The highest current amplitudes were observed majorly at odd frequencies at 3rd, 5th, 7th and 11th orders. The TDD% was found as high as 22% for cables connecting to EVCS at the LT side of EVCS, which was beyond the acceptable limit as per IEEE- 519, whereas around 6% at the HT side, which is within the acceptable limits. Similar results were observed at other locations where it is connected to EVCS. It is recommended that the EVCS locations should be checked and simulated for the presence and effect of harmonics; and appropriate filter configurations (Single/Double tuned) should be installed at the LT side of EVCS transformer to avoid early wear and tear of transformer and associated LV equipment.

In addition to this, the withstand rating for the service cables as well as overhead lines with Coyote and Rabbit conductors at various locations failed when harmonics were tested. These overhead lines should be appropriately replaced with higher short circuit rated conductors. It is also recommended to perform load flow analysis to find out the available hosting capacity of the feeder before any EVCS or additional SRTPV installation. Additionally, capacitor banks can be installed at necessary locations to compensate for reactive power and low voltage areas in the current scenario.

6 IDENTIFICATION OF LOCATIONS OF EV CHARGING STATIONS

6.1 Identification of Ideal Locations for EV Charging Stations in Bengaluru

To accelerate the adoption of EVs, the availability of adequate charging infrastructure is essential. The IS:17017 series standards for EVSEs issued by the Bureau of Indian Standards (BIS) allow both CCS 2 and CHAdeMO type of DC chargers besides AC Type 2 chargers. EVSEs conforming to Bharat Charger Specifications issued by DHI are also allowed in India. So, charging station operators have the freedom to install all or any of these chargers depending on the business volume.

The most critical factor for the installation of charging stations is investment related to connectivity with the distribution network. At certain locations the existing distribution network could connect to a charging station (say 50 kW or 100 kW or 200 kW) without significant enhancement to the grid capacity. But in many places, such connections would require installing a new DT and cabling, which can be very expensive. Therefore, it is essential to understand the following aspects at the city level for proper planning of charging infrastructure:

- Number of different types of EVs at the city level and its annual growth rate
- Typical battery charging load in EVs that may be added to the grid

- End-user behaviours for choosing EV charging locations - home, office, public charging; and charging types - slow (5 hours) or fast (1 hour); and charging time during the morning, afternoon, evening, night.
- Charger categories (slow/fast individual, centralised, bulk charging)

As stated in the previous chapter, BESCOM wishes to install 150 chargers in Bengaluru City in the near term. ISGF, in consultation with BESCOM, identified 300 locations across 19 areas in Bengaluru City based on the following parameters:

- Space availability
- Technical feasibility
- Distribution network availability
- Accessibility – expected number of users
- Protection/Safety requirements
- How much time EVs will stand at the charging stations (user convenience)
- The types of charging stations proposed for different locations are given in Table 6-1.

Table 6-1: Charging options identified for various vehicle categories

<table>
<tr><th>Vehicle Category</th><th>Home</th><th>Society</th><th>On-Street Parking</th><th>Work</th><th>Private (Dedicated)</th><th>Public Charging Station (PCS)</th><th>Commercial (E-Commerce Delivery Fleets)</th></tr>
<tr><td>2W</td><td>Slow AC</td><td>Slow AC</td><td>• Slow AC
• Battery Swap</td><td>Slow AC</td><td>• Slow AC
• Slow DC</td><td rowspan="3">Intracity:
• Slow AC
• Fast AC
• Slow DC
• Fast DC
• Battery Swap

Intercity/ Highways:

Same as Intracity, plus High-Power Fast DC</td><td>• Slow AC
• Fast DC</td></tr>
<tr><td>3W</td><td>Slow AC</td><td>NA</td><td>• Slow AC
• Battery Swap</td><td>NA</td><td>Battery Swap</td><td>• Slow AC
• Fast AC
• Slow DC
• Fast DC</td></tr>
<tr><td>4W</td><td>Slow AC</td><td>Slow AC</td><td>• Slow AC
• Fast AC
• Slow DC
• Battery Swap</td><td>• Slow AC
• Fast AC
• Slow DC</td><td>• Slow AC
• Fast AC
• Slow DC
• Fast DC
• Battery Swap</td><td>NA</td></tr>
<tr><td>Buses</td><td colspan="7">• Bus depots – Slow AC and Fast DC
• Bus terminus – Fast DC</td></tr>
</table>

6.2 List of Shortlisted Locations in Bengaluru City for EV Charging Stations

The shortlisted locations in below mentioned areas in Bengaluru City are as follows:

Table 6-2: Selected EV charging station locations across Bengaluru City

Sl No	Locality	Sl No	Locality
A	Jaya Nagar	K	Banaswadi
B	Electronic City	L	Nelamangala Town

Sl No	Locality	Sl No	Locality
C	Koramangala	M	Malleshwaram
D	Yeshwanthpur	N	Hebbal
E	Mahadevapura	O	HSR Layout
F	Marathahalli	P	Bommasandra
G	Whitefield	Q	Bannerghatta
H	K R Puram	R	Nagarabhavi
I	Yelahanka	S	Kengeri
J	Peenya		

Table 6-3: Selected EV spots across diffrent locations in Bengaluru City

Sl No	Area	Locations
A. Jayanagar		
1	Educational Institutions	Vijaya College, Jain (Deemed-to-be University), VEIT Degree College
2	Museums	Shiva Statue
3	Metro Stations	Jayanagar Metro Station
4	Hospitals	Bangalore Institute of Gastroenterology. Super Specialty Hospitals, Jayanagar General Hospital
5	Government Offices	BBMP Office
6	Commercial Centers- Malls, Movie Halls	INOX, The High Street
7	Big Hotels and Popular Restaurants & Bars	Hotel Pai Viceroy, La Marvella - A Sarovar Premiere Hotel
8	Tech Parks/Industrial Areas/Natural Parks	Ranadheera Kanteerava Park, Jayanagar Park
B. Electronic City		
1	Educational Institutions	PES University Electronic City Campus, IFIM Business School, Suvidya College
2	Bus Stations	B M T C Bus Depot 38
3	Hospitals	Springleaf Hospital, Narayana hridhayala
4	Government Offices	Bharat Heavy Electricals Limited, Karnataka State Small Industries Development Corporation Ltd
5	Commercial Centers- Malls, Movie Halls	Ittina Neela Shopping Complex, MMR Shopping Complex
6	Big Hotels and Popular Restaurants & Bars	The Oterra Hotel, Lemon Tree Hotel, Svenska Design Hotels
7	Tech Parks/Industrial Areas/Natural Parks	Velankani Tech Park, Prestige Sunrise Park, Bhavani Industries
C. Koramangala		
1	Educational Institutions	Jyoti Nivas Pre-University College, Krupanidhi Group of Institutions St. Francis College
2	Museums	Art Museum, Koramangala Monument
3	Bus Stations	Koramangala Bus Depot

Sl No	Area	Locations
4	Hospitals	Marvel Multispeciality Hospital, Apollo Spectra Hospitals, Devi Eye Hospital
5	Government Offices	Survey of India, NCDC Bengaluru, Koramangala Sub-Registrar's Office
6	Commercial Centers- Malls, Movie Halls	The Forum Mall Koramangala, Market Square Mall, Oasis Centre
7	Big Hotels and Popular Restaurants & Bars	Grand Mercure Bangalore, Halcyon Residences
8	Tech Parks/Industrial Areas/Natural Parks	BBMP Park, Wipro Park, Enzyme Tech Park
D. Yeshwanthpur		
1	Educational Institutions	Government Pre-University College, Srinivasa Vidya Niketan Bapu College of Education
2	Bus Stations	Yeshwantpur Bus Depot
3	Metro Stations	Yeshwanthpur metro station
4	Railway Stations	Yeshawanthapura Railway Station
5	Hospitals	Sparsh Hospital, People Tree Hospitals, ESIC model Hospital Peenya
6	Government Offices	Karnataka State Tourism Development Corporation, State Excise Department
7	Commercial Centers- Malls, Movie Halls	Orion Mall, Vaishnavi Sapphire Centre
8	Big Hotels and Popular Restaurants & Bars	Holiday Inn Express, The Fern Residency, Taj Yeshwantpur
9	Tech Parks/Industrial Areas/Natural Parks	JP Park Rocks Park
E. Mahadevapura		
1	Educational Institutions	Lowry Adventist College
2	Museums	Tin Factory
3	Hospitals	MTB Orthopaedic Hospital, Bright Childernes Clinic
4	Government Offices	Mahadevapura Sub Registrar's Office, Bruhat Bengaluru Mahanagara Palike
5	Commercial Centers- Malls, Movie Halls	Soul Space Arena Mall, Phoenix Market city
6	Big Hotels and Popular Restaurants & Bars	The Iris Inn
7	Tech Parks/Industrial Areas/Natural Parks	Mahadevapura Lake Park, Saturn Industries
F. Marathahalli		
1	Educational Institutions	Westford International College, Hindustan Academy
2	Museums	HAL Heritage Centre and Aerospace Museum
3	Metro Stations	Marathalli Metro
4	Hospitals	Rainbow Children's Hospital, Jeevika Hospital
5	Government Offices	BBMP Office
6	Commercial Centers- Malls, Movie Halls	KLM Fashion Mall, HomeTown
7	Big Hotels and Popular Restaurants & Bars	Radisson Blu Bangalore Outer Ring Road, Octave Hotel & Spa Marathahalli
8	Tech Parks/Industrial Areas/Natural Parks	Prestige platina tech park, Salarpuria Sattva Supreme, Nisarga Park

Sl No	Area	Locations
G. Whitefield		
1	Educational Institutions	Ujjval Vidyalaya Composite School & PU College, MVJ College of Engineering
2	Museums	VIDA Museum of Anatomy, Click Art Museum
3	Bus Stations	ITPL main bus station
4	Metro Stations	Metro Station
5	Hospitals	Columbia Asia Hospital Whitefield, Cloudnine Hospital, Svastha Hospital
6	Government Offices	Office of The Development Commissioner (Handicarfts), Ministry of Textiles, Govt. of India
7	Commercial Centers- Malls, Movie Halls	The Forum Neighbourhood Mall, Inorbit Mall Whitefield, Virginia Mall
8	Big Hotels and Popular Restaurants & Bars	Hotel Royal Orchid Suites, Lemon Tree Hotel, Ginger Bangalore
9	Tech Parks/Industrial Areas/Natural Parks	International Tech Park Bangalore (ITPB), Sumadhura Capitol Towers, H M Tech Park
H. K R Puram		
1	Educational Institutions	St Anne`s Pre-University College for Girls, Garden City University
2	Bus Stations	K R Puram Bus Depot No 24
3	Metro Stations	KR Puram Metro Station
4	Railway Stations	KR Puram Railway Station
5	Hospitals	Sathya Sai Orthopaedic and Multi-specialty Hospital
6	Government Offices	Sub Registrar Office Krishnarajapuram, KR Puram RTO, Taluk Office
7	Big Hotels and Popular Restaurants & Bars	KR inn, Y N Hotels
I. Yelahanka		
1	Educational Institutions	Seshadripuram Pre University College, Government First Grade College Yelahanka, Nagarjuna Pre University College
2	Bus Stations	BMTC Bus Terminal
3	Railway Stations	Yelahanka Junction
4	Hospitals	Ashwini Hospital, K K Hospital, Apple Hospital
5	Government Offices	Yelahanka Taluk Sub Registrar Office, Range Forest Office
6	Commercial Centers- Malls, Movie Halls	RMZ Galleria Mall, Kurlappa Shopping Complex
7	Big Hotels and Popular Restaurants & Bars	Royal Orchid Resort & Convention Centre, Treebo Trend Rotano Suites Yelahanka
8	Tech Parks/Industrial Areas/Natural Parks	Rajiv Gandhi Park, Yashu TEC
J. Peenya		
1	Educational Institutions	M S Ramaiah University of Applied sciences, Vidya Soudha PU College
2	Bus Stations	Shree Basaveswara KSRTC Bus Stop
3	Metro Stations	Peenya Metro Station
4	Hospitals	ESIC model Hospital
5	Government Offices	NSIC Peenya, Sub Registrar Office Peenya

Sl No	Area	Locations
6	Big Hotels and Popular Restaurants & Bars	Oasis Executive Suites
7	Tech Parks/Industrial Areas/Natural Parks	Peenya Park, Lake Park
	K. Banaswadi	
1	Educational Institutions	CMR Law College and Center for Business Studies
2	Government Offices	Sub Registrar Office, MLA Office Banaswadi
3	Commercial Centers- Malls, Movie Halls	Orion Avenue, Sankhla Complex
4	Big Hotels and Popular Restaurants & Bars	Hotel Elcielo
5	Tech Parks/Industrial Areas/Natural Parks	OMBR Layout Park
	L. Nelamangala Town	
1	Educational Institutions	Soundarya Ambika Pre-University College, Harsha School and College of Nursing
2	Bus Stations	Nelamangala Bus Station
3	Hospitals	MS Ramaiah Harsha Hospital, Sharada hospital
4	Government Offices	Nelamangala Taluk Office, Nelamangala Planning Authority
5	Big Hotels and Popular Restaurants & Bars	Hotel Kempegowda Lodging and Boarding
6	Tech Parks/Industrial Areas/Natural Parks	Vijayanagar park, Sabera Park
	M. Malleshwaram	
1	Educational Institutions	Vidya Mandir Ind. Pre University College, Government Boys Pre-University College, Maharani Lakshmi Ammanni College for Women
2	Bus Stations	Malleshwaram Bus Stand
3	Hospitals	Manipal Hospital, Cloudnine Hospital, K.C. General Hospital
4	Government Offices	Karnataka Forest Department Headquarters
5	Commercial Centers- Malls, Movie Halls	Mantri Square Mall
6	Big Hotels and Popular Restaurants & Bars	Sheraton Grand Bangalore Hotel at Brigade Gateway, Collection O 30004 Malleshwaram
7	Tech Parks/Industrial Areas/Natural Parks	Dr Rajkumar Park
	N. Hebbal	
1	Educational Institutions	Veterinary College, Atria Institute of Technology, Presidency College
2	Museums	Hebbal Lake Park
3	Bus Stations	BMTC Hebbal Bus Depot
4	Hospitals	Bangalore Baptist Hospital, Ehaa Hospital, Columbia Asia Hospital
5	Government Offices	Agricultural and Processed Food Products Export Development Authority, Central Bureau of Investigation, Office of Excise Inspector, Karnataka State Seeds Corporation Limited
6	Commercial Centers- Malls, Movie Halls	Esteem Mall, City Centre, City Pearl Super Market

Sl No	Area	Locations
7	Big Hotels and Popular Restaurants & Bars	The Royale Senate, Courtyard by Marriott Bangalore Hebbal, Kanaka Grand Hebbal Hotel Bangalore
O. HSR Layout		
1	Educational Institutions	SVR Pre-University College
2	Museums	Healthsignz Technologies Pvt Ltd, Quvideo Technologies India Pvt Ltd, Tree Park, Invenger Towers
3	Bus Stations	BMTC Bus Depot Agara
4	Hospitals	Matoshree Kidney Stone Centre & UroNephro Clinic, Narayana Multispeciality Hospital, Queen's Hospital
5	Government Offices	Office of The Commandant 3rd battlion KSRP, Bescom Integrated Control Centre, BBMP Office HSR Layout
6	Commercial Centers- Malls, Movie Halls	KLM Fashion Mall
7	Big Hotels and Popular Restaurants & Bars	FabHotel Astra Suites, DoubleTree Suites by Hilton Hotel OYO Townhouse 049 HSR Layout
8	Tech Parks/Industrial Areas/Natural Parks	Swachagraha Kalika Kendra
P. Bommasandra		
1	Educational Institutions	BTL Institute of Technology & Management, Narayana Hrudayalaya College of Allied Health Science
2	Hospitals	Sparsh Hospital, Narayana Institute of Cardiac Sciences, Mazumdar Shaw Medical Center, NH Health City - Platinum Wing
3	Government Offices	Municipality Office, Chandapura Purasaba Office
4	Commercial Centers- Malls, Movie Halls	Medhini Arcade
5	Big Hotels and Popular Restaurants & Bars	Southend by TGI, Hotel Jade Empire, T S Royal Grand Hotel
Q. Bannerghatta		
1	Educational Institutions	Administrative Management College, SVKM's Narsee Monjee Institute of Management Studies
2	Museums	Bannerghatta Museum
3	Hospitals	NSVK Dental College and Hospital
4	Government Offices	Bannerghatta Panchayath Office, Bannerghatta Police Station, M R O Office
5	Commercial Centers- Malls, Movie Halls	Royal Meenakshi Mall, Gopalan Innovation Mall
6	Big Hotels and Popular Restaurants & Bars	Park Hotel and Resort, Radiant Resort
R. Nagarabhavi		
1	Educational Institutions	Karnataka Lingayat Education Society, Maulana Azad National Urdu University Polytechnic, Vijayanagar College of Nursing, Mahesh PU College Nagarabhavi
2	Bus Stations	Bande Maramma Bus Station
3	Hospitals	Fortis Hospital, Brinda Hospital, Chandana & Miracle IVF Hospital Amulya Ayurveda Health and Wellness Center
4	Government Offices	BBMP Kottegepallya Ward Corporator Office, Deputy chief Electrical Inspector Bengaluru Additional West Office, Bangalore One Integrated Citizen Service Centre

Sl No	Area	Locations
5	Commercial Centers- Malls, Movie Halls	G Mart
6	Big Hotels and Popular Restaurants & Bars	Terminal Square, Sri Nandi Comforts, Ayodhya Grand Hotel Nandhana Palace, Mane Ruchi's Palate
7	Tech Parks/Industrial Areas/Natural Parks	Mahatma Gandhi Bda Park
S. Kengeri		
1	Educational Institutions	Kengeri First Grade College, Kengeri Pre University College SJB Institute of Technology, Bangalore Institute of Management Studies
2	Bus Stations	Kengeri Bus Terminal
3	Railway Stations	Kengeri Railway Station
4	Hospitals	Kengeri Government Hospital, P M Santosha Hospital, H.K. Hospital Raja Rajeswari Medical College and Hospital
5	Government Offices	BBMP Office, Deputy Tahsildar Office, Nadakacheri, Kengeri Sub Registrar Office, Kengeri Police Station
6	Commercial Centers- Malls, Movie Halls	Gopalan Arcade Mall, SLNS Complex
7	Big Hotels and Popular Restaurants & Bars	Hotel the Prince Royal, Hotel Kadamba Guestline
8	Tech Parks/Industrial Areas/Natural Parks	Composite technology park, Global Village Tech Park, Kengeri Satellite Town Park

The location details with Google Map are given in Annexure - VI.

These locations are plotted on GIS Map in order to avoid duplications in the same localities. Also, consideration for the case of access and availability of space for vehicle to park and nearness to distribution transformers are considered.

ISGF has identified particular locations in different localities. BESCOM needs to get in touch with property owners to identify mutually convenient spots for installing EVCS and determine the availability of the power distribution network for that exact location from BESCOM's nearest DT. ISGF has suggested office complexes, educational institutions, hospitals, railway stations, bus stands, religious places, shopping malls, and other popular areas within the city. Most appropriate spots in those locations for installing EVCS from user convenience, space availability, nearness to the grid, and other considerations may be reviewed by BESCOM in consultation with the property owner.

The time taken for charging an EV depends upon the battery size of the EV, the state of charge of the EV battery when it comes to charging (50% drained out or 70% drained out), the capacity (kW) of the charger and the C-rate of the EV Battery. The type of charging station will depend on user footfall and type of usage/ customer at an individual location. Data collected from the existing charging station can help to find out a thumb rule for the same. Physical surveys of such locations are out of the scope of this study.

7 BUSINESS MODELS FOR EV CHARGING STATIONS

Typically, the rollout of EVs and EV charging stations follow the classic conundrum challenge of which one to come first. EV buyers are apprehensive of the availability of adequate charging stations to adopt EVs, while charging station operators are doubtful about the sustainability of EV charging business owing to the lack of EVs in a city/region. During the initial phases of EV rollout, the EV stock being minimal, utilisation of charging stations will be very poor, and investors must be incentivized to come forward and set up EV stations. EV charging infrastructure in North America, Europe, and Japan was initially set up with different grants and support from national and city governments. The total number of charging stations across India installed by different agencies are given in the Table below:

Table 7-1: Public chargers installed by agencies

Sl No	Agencies	No of Public Chargers Installed
1	Energy Efficiency Services Limited (EESL)	92
2	National Thermal Power Corporation Limited (NTPC)	90
3	Rajasthan Electronics & Instruments Limited (REIL)	270

Sl No	Agencies	No of Public Chargers Installed
4	Power Grid Corporation of India (PGCIL)	10
5	Oil Marketing Companies	120
6.	Tata Power Company Ltd	500
7.	Bangalore Electricity Supply Company Ltd (BESCOM)	136
8.	Fortum	60
9.	Other Players	189
Total		1,467

Source: EESL and other reports

The GoI, under the FAME II scheme, has allotted a grant for setting up 2,636 charging stations in cities and highways across 24 states and Union Territories[11]. Under this scheme, a nodal agency has been nominated in each state, which will plan and coordinate the installation of the charging stations.

7.1 EVSE Business Models – International Experiences

By the end of 2019, there were about 7.3 million EV charging points, of which 89% were privately owned slow chargers (or home chargers). Worldwide 7.2 million EVs have been sold out until the end of 2019. The total number of EVSE in some countries are given in Table 7-2.

Table 7-2: EV Charging points in few countries

Number of EV Charging Points in few Countries (Indicative only)			
Country	2017	2018	2019
USA	45,868	61,067	77,358
Canada	5,841	8,148	8,951
Japan	28,834	26,950	30,394
Korea	5,612	15,000	29,309
Norway	9,530	13,290	11,260
France	15,978	25,140	29,701
Netherlands	33,431	36,414	50,153
Germany	24,289	38,430	38,520
China	2,13,903	2,74,270	5,15,908

Source: Global EV Outlook 2020, IEA

Different countries took different approaches in the creation of EVSE ecosystem with mixed results. There are two main approaches as described below:

Integrated Model: The electric utility owns the EVSE and operates it directly or through its franchisees (or contractors). The EVSE asset forms part of the regulated assets of the utility responsible for distribution of electricity and operation and maintenance of the EVSE. The most popular example of this model is Ireland and British Columbia in Canada. The main advantage of this model is that the utility need not to worry about the low volume of EV charging business in the initial years as these assets are created under-regulated CAPEX route for the grid infrastructure, which is paid back from the electricity tariff for the state or province.

Independent Model: In this case, independent private private or (public-private partnerships) players set up EVSE under licenses from local governments or municipalities. They may appoint EV Service Providers (EVSP) for charging operations and payment settlements, ensuring certain interoperability levels amongst different EVSE network owners. UK and Netherlands are examples of the Independent Model. Different countries and local governments offer different incentives, tax breaks etc. to EVSE network owners to compensate for low business volumes in the initial years.

[11] *List of the charging stations allotted under FAME II Scheme is given in Table 3-2*

Both models exist in different parts of the USA. Different financial packages are offered under different policy initiatives to incentivize both EVs and EVSE ecosystem in almost all European countries and the USA. A comparative table of EVSE ecosystem in select countries is given in Table 7-3:

Table 7-3: EVSE business models in select countries

Country	United Kingdom	Ireland	Netherlands	United States	Germany
Total EV stock	16,4100	2,687	1,71,317	14,50,000	59,090
Normal Charge Points Fast Charge	7,439	1,000	49,324	64,265	35,880
Points	29,514	172	829	13,093	2,640
Total Charge Points	36,953	1,009	50,153	77,358	38,520
Charging Market Model	Independent	Integrated	Independent	Independent	Independent
Public Charging Organization	By local authorities, over discrete platforms	By the grid operator	By local authorities, over open access platforms	By charging network operators and property owners on discrete platforms	Over three quarters of charging points are operated by electricity companies
Private Operators of Public Charging	5-10	0-5	15-20	10 networks, many property owners	
EVSE Owner	Infrastructure is tendered by local governments like cities, regions or municipalities	Infrastructure in the hands of e-cars, a subsidiary of ESB (grid operator). ESB tenders charging hardware and installation	Cities and provinces tender public charging infrastructure	Third party charging service provider, individual residents, homeowner associations etc.	Municipal governments and private investors
EV Service Providers (EVSP)	Operation is done by private parties that subcontract their energy supplier	Subcontractors of ESB operates the EVSE	Private companies, energy companies and contractors operate as EVSPs	Private EVSPs	Private EVSPs
Entity Responsible for Grid Upgradation	Grid operator	ESB-Ireland's grid operator	EVSE Owner		Private investor but the Govt funding will cover network connection cost
Interoperability	No national interoperability between EVSEs in different UK regions, however, interoperability within regions is organized by EVSPs	EVSPs offer subscriptions to EV Owners and delivering interoperability in return, using an RIFD card for authentication in the transaction	National interoperability is organized through the Central Registry Interoperability and is managed by noncommercial organization eViolin to which all EVSEs and EVSPs are connected	No national interoperability between EVSEs in USA	Ladenetz, a government sponsored consortium of utilities, universities, and private EVSPs in Germany and the Netherlands, is creating a Europe-wide network of interoperable charging stations

Source: ISGF –Electric Vehicles Charging Stations Business Models for India[12]

[12]*ISGF - https://bit.ly/2LUIbEq*

7.2 Present Scenario of EV Charging Stations in India

Installation of public charging stations in India started with few electric utilities on a pilot project basis, followed by large-scale implementations by Energy Efficiency Services Limited (EESL). The GoI mandated EESL to procure EVs and lease it to ministries and government institutions. As part of this EV leasing services, EESL has installed 127 public chargers across India, out of which 81 chargers are installed in NCT Delhi. Some private entrepreneurs have also set up charging stations in different cities. The list of charging stations allotted under FAME II is given in Table 3-2.

7.2.1 EV Charging Business by BESCOM

Under the Karnataka EV Policy, BESCOM has been given a capital subsidy for installing 136 chargers at 74 locations in Bengaluru City. The cost details of the chargers are given in Table 7-4:

Table 7-4: CAPEX of BESCOM charging stations

SI No	Location	Substation Name	No. of DC Chargers	Cost of EVSE (INR in million)	Cost of Upstream Infrastructure (INR in million)
1	Corporate Office	KR Circle	4	2.7	0.2
2	N4 Sub-Division Office	Peenya	2	1.35	2
3	C6 Sub-Division Office	Mathikere	2	1.35	2
4	C7 Sub-Division Office	Yelahanka	2	1.35	2
5	E8 Sub-Division Office	Banaswadi	2	1.35	2
6	Indiranagar Division Office	HAL 2nd Stage	2	1.35	2
7	Mahadevapura O&M Office	Mahadevapura	2	1.35	2
8	S17 Sub-Division Office	Murugeshpalya, HAL	2	1.35	2
9	HSR Division Office	HSR 2nd Sector	2	1.35	2
10	BTM O&M Unit -2	BTM Layout	2	1.35	2
11	Kathriguppe O&M Office	Kathriguppe	2	1.35	2
12	W6 Byatarayanapura Sub Division	Byatarayanapura	2	1.35	2
13	BESCOM Corporate Office-1	BESCOM	2	1.35	2
14	Vidhana Soudha	BESCOM	2	1.35	2
15	Vikasa Soudha	BESCOM	2	1.35	2
16	AC Chargers	104	4.68	1.04	
17	Total	136	26.28	29.24	
18	Grand Total				55.52
17	Subsidy			16.8	0.00

7.2.2 Electricity Tariffs for EV Charging in Karnataka

Karnataka Electricity Regulatory Commission (KERC) issued separate tariffs for EV charging in 2020. The latest applicable tariffs are given in Table 7-5.

Table 7-5: Electric vehicle charging stations tariff

Fixed/ Demand Charges per kW	LT	HT
	INR 70 /kW/month	INR 200 /kVA/month
Energy charges per kWh (For both LT and HT)	INR 5.00/unit*	

**There are different taxes and duties over and above these rates, which vary from state to state[13]*

7.2.3 Evaluation of EV Charging Station Business of BESCOM

As described in the above chart, BESCOM invested about INR 22.1 million towards procuring the EVSE and another INR 23.2 million towards upstream infrastructure. They have received a subsidy of INR 16.8 million from the state government for the EVSE. Presently all 74 locations where EVSEs are installed are BESCOM's office premises or substations. Hence there is no cost for the land or parking fee they have to pay to the City Government; however, BESCOM is presently keeping a dedicated Operator to manage each of the charging stations. The monthly wages and allowances for the Operator is INR 40,861/-.

The electricity rate BESCOM charges from EV owners and BESCOM's charging station has to pay to BESCOM for the electricity consumed are presented in Table 7-6. The average monthly sale of electricity to EVs per charging station is around 4000 to 5000 kWh. For calculations, the study assumed 4500 kWh/month for a typical charging station with 3 chargers and a maximum connected EVSE load of 44 kW.

Table 7-6: EV charging revenue for BESCOM

Type of Charger	Rate/kWh charged from the EV Owner (INR)	BESCOM's Electricity Cost per kWh (as per KERC Tariff) (INR)	kWh Sold per Month (INR)	Revenue from EV Charging (INR)	Electricity Charges (Demand Charges + Energy Charges) * (INR)	Total OPEX including Operator Wages (INR)	Net Margin per Month (INR)
AC Charging (AC001)	7.44	5.00	1000	7440	4500 x 5 + 44 x 70 = 25580	25580 + 40861	
DC Charging (DC001)	7.58	5.00	1500	11370			
DC Fast Charging CHAdeMO/ CCS2	8.25	5.00	2000	16500			
Total			4500	35310	25580	66441	(-) 31131
Net Margin if Operator Cost is removed							9,730

**Taxes and duties not considered in this calculation could be about INR 0.70 per kWh; also, rental/charges towards the software platform and payment gateway, security charges, etc. are not considered.*

[13]Taxes applied in Karnataka are: 1. Power Purchase Adjustment Charges (PPAC) – 5%, Pension Surcharge – 3.8%, Regulatory Surcharge – 8%, Electricity Duty – 5%

From the above analysis, there are huge losses being incurred by BESCOM in each of the charging stations. Even if the operator cost is removed, the business volume is too low to meet the operational costs. Return on investment cannot be expected anytime soon. The Table below analyzes different scenarios of EV charging business volumes and different rates for EV charging to be levied from EV Owners.

Table 7-7: EV charging business scenario for BESCOM

Scenarios	Description	EV Charging Revenue per EVCS per Month	Electricity Charges per Month per EVCS	Net Margin Per Month per EVCS	Remarks
Scenario-1	EV stock in Bengaluru increases by 10X and Average Charging Business Volumes also increases by 10X; rates for EV charging and electricity tariff remain the same	353,100	255,800	97,300	Taxes and duties on electricity rate, software platform and payment gateway charges, insurance fee on EVSEs, Security and Parking Fee/ Land Lease charges not considered
Scenario-2	The Net Margin (difference between BESCOM's EV Charging Rate levied from EV Drivers and BESCOM's Electricity Charges as per KERC Tariffs) is doubled	45,040	25580	19,460	
Scenario -3	Combination of both Scenario-1 and Scenario-2 (10X business volume and 2X net margin)	450,400	255,800	194,600	

While scenario 2 of increasing the rate levied from EV owners for charging can be increased by BESCOM anytime, the increase in EV stock in the City/State depends on several external factors on which BESCOM (or any charging station operator) has no control. EV stock increasing by 10X from present levels is not expected before 2025. During the first 9 months of 2020, only about 1800 electric cars were sold in India despite several new models introduced by car manufacturers.

7.3 EV Charging Business of EESL

EESL has 92 charging stations operational in India as of 2020, out of which 55 charging stations are in Delhi. The margins for EESL based on their rates for EV charging from EV Drivers and the electricity tariff in Delhi is presented below.

Table 7-8: EV charging revenue for EESL

Charger Type	Average Daily Hours of Operation	Energy Consumption (kWh) per Month (kWh)	Rate Charged from EV Drivers (INR/kWh)	EV Tariff in Delhi (INR/ kWh)	Monthly Charging Revenue (INR)	Gross Monthly Margin per Charging Station (INR)	Remarks
Bharat Charger AC 3.3 kW	4	396	7.50	5.50	2970	792	Effective rate including taxes and Duties is taken at INR 5.50; No fixed charges in Delhi
Bharat Charger DC 15 kW	4	1800	10.00		18,000	8100	

Charger Type	Average Daily Hours of Operation	Energy Consumption (kWh) per Month (kWh)	Rate Charged from EV Drivers (INR/kWh)	EV Tariff in Delhi (INR/ kWh)	Monthly Charging Revenue (INR)	Gross Monthly Margin per Charging Station (INR)	Remarks
DC Fast Charger 140 kW	10	6000*	26.00		156,000	123,000	
Total		18,996			176,970	131,892	

Source: Publicly available information and estimates

** Although the DC output of this charger is 140 kW, the presently available EVs in India with battery sizes varying from 18 kWh to 39 kWh and charging speed of 0.3C to 1C rate cannot make use of the high power. Hence, we assumed 10 hours of daily charging with average output of 20 kW. Power loss during AC-DC conversion in the DC chargers are not factored in the calculations above.*

EESL does not engage Operators at charging stations. The EVSE units are insured and have security cameras installed which are remotely monitored. The annual insurance premium for such infrastructure is around 1% of the CAPEX. Most chargers are installed at government offices and other public places. EESL has entered into a strategic alliance with New Delhi Municipal Corporation (NDMC) to install chargers in NDMC area. The above analysis does not include the cost of the software platform, payment gateway charges, insurance premium, solution for remote monitoring of the EVSEs, and the parking charges/lease rent for the land.

The approximate CAPEX for a charging station with the chargers is listed in Table 7-8 is about INR 3 million, in addition to this installation charges and electricity connection charges, varying from location to location and could be in range of INR 0.4 to 0.5 million. The gross margin of INR 131,892 is mainly contributed by 140 kW DC Fast Charger with a rate of INR 26/kWh. This is about 5 times of the electricity input cost. Most public charging stations in Europe and America charge 3 to 5 times the electricity input cost. However, in the Indian context when there will be competition, 5X rates may not be sustainable. Most operators will be charging 2-3X of the electricity tariff from the grid. Therefore, even at INR 26/kWh and INR 10/kWh for fast charging in Delhi where electricity input cost is INR 5.5/kWh, the net margin of EESL may not be sufficient to pay back the investment in reasonable time unless the charging business volume increase significantly.

7.4 Other Charging Station Operators in India

Other prominent charging station operators are NTPC, POWERGRID, REIL, Fortum and Tata Power etc. Unfortunately, we could not get reliable data about their charging stations and the rate they charge from the EV Drivers. Although the correct rates from agencies levy for EV charging are not available, our unverified information indicates that they all levy much higher than BESCOM. For example, Fortum operates 60 numbers of 15 kW DC 001 and 60 kW CCS2/CHAdeMO chargers and levied INR 22/kWh from EV drivers.

In Bengaluru City, following charging station operators are providing services:

1. **Bhagirathi (rYDES)** Operate 10 AC 001 (3x3.3 kW) chargers and 8 DC 001 (15 kW) chargers in Hoody and Bengaluru for their fleet
2. **Lithium** has 120 DC 001 chargers of capacities 15 kW installed in various buildings in Bengaluru
3. **Ather Energy** also has set up about 40 chargers in Bengaluru at Cafes/Gyms etc,

where they are offering charging services to their make of scooters as well as other EVs

7.5 Criteria for Selection of EVSEs for Public Charging Stations

Ministry of Power issued guidelines on the sizes of EVSEs to be installed at public charging stations, which recommends AC Type 2 Chargers of 22 kW and CCS2 and CHAdeMO chargers of 50 kW. Some fundamentals to be understood while selecting the charger sizes are listed below.

- The amount of electricity that an EVSE can transfer to an EV depends on the battery size and the rate or speed at which the battery can be charged which in turn depends on the battery chemistry
- In the case of AC chargers, the charging rate depends on the capacity of the AC-DC converter onboard the EV. Most EVs have small size onboard AC-DC converter to keep the weight and cost of the EV low. For example, an EV with a 20 kWh battery and an on-board AC–DC converter of 2 kW DC output will take 8 hours to fully charge (from 80% DoD[14] condition) irrespective of whichever charger is used – AC 001 of 3.3 kW or a Type-2 Charger of 7.5 kW or 22 kW
- In the case of DC Charger, the rate of charging depends on the C-rate[15] of the battery. Most EVs sold in India have a charging rate of 0.3C or 0.5C, which means it takes 3 hours or 2 hours to charge. Hyundai Kona is the first EV introduced in India with a 1C battery which can be charged in one hour (or in 45 mins from 80% DoD)
- To charge an EV with a 50 kWh battery that can be charged at 4C rate in 15 mins require a 200 kW charger

While choosing the EVSEs for a public charging station, the EV stock in the locality and the battery sizes and characteristics as well as the above indicators shall be considered.

7.6 Factors to be considered for EV Charging Rate

Following are the key factors to be considered while framing the EV charging rates by charging station operators:

Table 7-8: EV charging revenue for EESL

CAPEX	OPEX
1. Cost of EVSE units (including taxes, insurance and transport to site of installation)	1. Electricity charges including all taxes and duties
2. Civil and Electrical Work (including cost of Meter, Meter Box, Distribution Panel, Wiring, Canopy, Barricades) for EVSE Installation, Earthing, Testing and Commissioning	2. Cost of Power Loss in DC Chargers due to AC-DC conversion
3. Electricity Connection from the Utility – Security Deposit, Cabling and transformer (where ever applicable)	3. Land Lease/Parking Fee (if applicable)
4. Cost for Mobile App, Payment Gateway and Communication System setup	4. Operational Cost of Mobile App, Payment Gateway and Communication System (SIM cards), Security Camera System (or Security Guards)
5. Security Camera and Remote Monitoring Systems	5. Insurance Premium for EVSE units
	6. AMC for EVSE units
	7. Facilities Management at the charging station
	8. Marketing Expenses

[14]Depth of Discharge (DoD) is the maximum level to which an EV battery can be discharged. Typically, in all EVs DoD is programmed at 80% which means when an EV comes to the charging station there will be minimum 20% or more charge left in the battery. So, 80% of the battery capacity is the maximum electricity that can be sold to the EV.

[15]C-rate of a battery depends on the battery chemistry. If a battery can be fully charged in one hour it is called 1C; and it can be charged in 30 mins, it is 2C and if the battery needs 2 hours to charge, it has 0.5C rate.

7.7 EV Charging Rate Models

Different models followed for EV charging rates are as described below:

- **Energy Sale**: This is the most popular method in which the Charging Station Operator charges the EVs to sell electricity in kWh. Different rates may be applied for AC slow charging and DC fast charging
- **Parking Fee**: In this scheme, the EVs are billed for the total time it is connected to the EVSE. Typically applied where slow chargers are deployed
- **Fixed Fee/Membership**: Some Charging Station Operators offer fixed fee per charge or fixed monthly subscription fee or premium memberships based on a monthly fee system
- **EV OEM Offers Free Charging**: Some EV OEMs do set up charging stations at popular places and offer free charging for their EV models, and charge money from other types of EVs

In India, presently operators are mostly charging for energy sold – INR/kWh basis. However, Ather Energy offers a monthly subscription plan.

7.8 BMTC's Charging Requirements for Electric Buses

Bengaluru Metropolitan Transport Corporation (BMTC) has been planning to introduce electric buses for the past few years. Under the FAME I scheme, they were allotted 40 buses, which they could not procure on time. Under the FAME II, they have been allotted 300 buses, which is in the process of rollout. However, no details related to their electric bus charging requirements could be obtained.

Electric buses have battery sizes varying from 120 kWh to 320 kWh, and charger ratings are also over 100 kW capacity. Charging several buses simultaneously in one bus depot requires a new power connection exceeding a few MWs and requiring full electric infrastructure upgrades, including new transformers. The sizing of the grid equipment for such connections may be done after detailed load flow and harmonics analysis and install harmonic filters of appropriate sizes and power quality meters[16].

ISGF had requested BESCOM to get the electric bus rollout plan of BMTC; however, the project team could not receive any data. At the time of finalizing this report in July 2021, BMTC was still under negotiations for buying 100 electric buses under the FAME II scheme. Therefore, no rollout plans were available. The study recommends that BMTC/BESCOM should not put more than 10 busses in one depot for charging simultaneously. BMTC has to provide the bus route plan and where the charging station is installed to understand the load impact on feeders. BESCOM should assess the technical feasibility of providing electricity connection for bus charging in bus depots. If more than 100 kW of chargers are installed at any location, there must be a power quality meter; and BESCOM should monitor it. ISGF recommendations to bus charging in Depots are given at Annexure - V.

7.9 Recommendations for EV Charging Business

In conclusion, the EV charging business is not sustainable as a standalone venture anytime soon. And in the present scenario, it is difficult to attract private investors to set up and operate EV charging stations. While the government grants and tax breaks could help this industry take off the ground and encourage the early adopters. There is still a need to facilitate and promote EVSE. The models given below can be looked into, which solve the discussed challenges and pave a path for better EV infrastructure and a more efficient energy market.

[16]ISGF Report on PMPL, Pune Bus Depot Incident in 2019: https://bit.ly/3cj04rp

1. A large business that benefits from EV sales and uses or seeks to gain marketing advantage (retail or restaurant) can contribute funding to subsidize the deployment of a DC fast-charging network for interregional EV travel
2. A group of local businesses could contribute annually to a fund pool that can subsidize the deployment charge and facilitate EV travel within the region. These businesses can be tourism or retailers
3. Another model can be as providing the charging network owner-operator with upfront and annual subsidies from a large business and a group of large business
4. Fleet operators and car rental companies may be allowed to set up EVSE networks
5. Retailers, shopping centres, hotels, fast food outlets, car parking providers, and all kinds of businesses with off-street parking can now offer EV charging with low effort, and this can be known as Commercial EVSE
6. EV manufacturers to contribute a certain percentage of the vehicle cost towards EVSE Fund which will be utilised to build EVSE network in respective cities/states
7. City governments/Municipalities and Highway Authorities may be mandated to allot space for EVSE networks on long lease at concessional (or free) through transparent selection route avoiding the creation of monopolies
8. In order to promote EVSE infrastructure and EV usage, incentives should be given in the form of tax concessions, long-term leases, or grants
9. Cities or areas, which attract large amounts of tourists should ban entry of petrol and diesel vehicles and should set up EVSE infrastructure
10. Smart chargers can be used to cut off power to particular vehicles once it reaches 70%-80% of charging and divert the same to other cars. Most of the offices in India are small and distributed. So, we can have a common parking tower for all the offices at a particular zone where smart charging can be implemented, which will otherwise minimize the individual implementation cost

Charging station business models that rely solely on direct revenue from EV charging services currently are not financially feasible, to build a business case that will attract capital and convince the private sector to invest in EV charging, total revenues must be greater than the project's total cost, and an acceptable level of profit is necessary.

There are four general ways to improve the financial performance of charging station projects: increase revenues, decrease capital costs, decrease operating costs, and/or decrease the cost of funds for the project. One promising opportunity to improve the financial performance of charging station investments is to develop business models that, through private partnerships and joint investment strategies, capture other types of business value in addition to selling electricity.

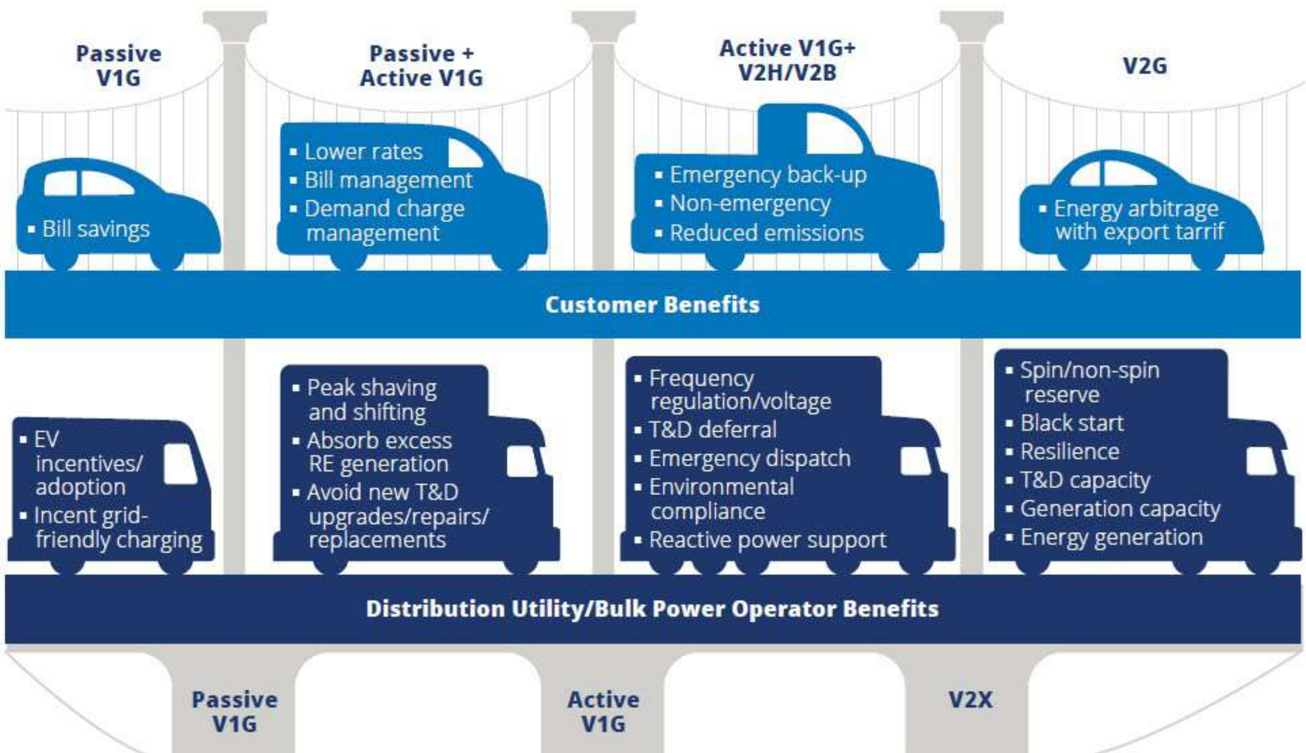
Some of the examples might include tourist revenue for retailers and tourism businesses that get more sales from EV drivers when located near EV charging stations; automakers selling more EVs; and "clean energy" marketing and brand-strengthening opportunities for businesses visibly involved in EV charging deployment projects.

7.10 Vehicle-Grid-Integration (VGI)

Vehicle-Grid-Integration (VGI) technologies have been successfully tested in several research labs and universities and are commercially deployed in few places. But most EV manufacturers are apprehensive of the effect of specific VGI methodologies on battery life and battery warranties. The life of a battery is based on the number of charge-discharge cycles. Certain VGI services, such as vehicle-to-grid (V2G) operations, where the battery is discharged to feed electricity to the grid, can cause battery warranties and degradation. So, theoretically, for V2G services, the life of the battery can reduce in terms of years of service. Many V2G trials have shown that if the Depth of Discharge (DoD) is maintained above 50% of the battery capacity, the effect of V2G operations on battery life will be minimal. However, other alternatives such as V1G, where battery is managed smartly to charge based on the grid conditions or real-time prices has no adverse impacts on the batteries and can immediately considered for EVs and charging infrastructure. A 2017 report by University of Warwick "On the possibility of extending the lifetime of lithium-ion batteries through optimal V2G facilitated by an integrated vehicle and smart-grid system" describes the "massaging effect" on the EV batteries through partial charge-discharge cycles that could extend the life of lithium- ion batteries. From the future-proofing context, it is recommended that by regulation of VGI services should be enabled in all EVs sold in India. This will greatly support the grid with increasing share of renewable energy, though location-specific constraints may be considered. The EV charging stations can also offer grid balancing and ancillary services to electric utilities, compensating the charging stations owners/operators. EV charging stations may opt on a subscription basis to facilitate: (a) Load Balancing; (b) Ancillary Services; (c) Demand Response; and (d) Other Load Time Shifting Requirements that the utilities would prefer.

VGI journey of a utility is described in the VGI Benefit Bridge below:

Figure 7-1: VGI benefit bridge



Source: Smart Electric Power Alliance, 2020.

Utilities may start this journey by offering EV-specific residential time-varying tariffs, motivating EV owners to charge during off-peak periods. In this type of passive mode of managed charging, the utilities communicate the tariff signals to the EV customers through messaging services or customized apps. This is also known as V1G charging. However, as the adoption of EVs increases, many EV owners start leveraging the off-peak subsidized tariffs and program their EVs to start charging during the off-peak tariff hours. This increased charging during off-peak hours will create "EV Peaks" which could overload the distribution networks or even increase the overall utility load. To balance these overload conditions. the utilities need to switch off some EVSEs at some/all locations. For this, EVSEs need communication and control capabilities with the utility control centres. This type of V1G charging with communications and control capability is known as Active V1G Charging. The next level is Vehicle to Home (V2H), Vehicle to Building (V2B) or Vehicle to Grid (V2G) integration. In this mode, the charging is bi-directional, and the EV batteries could import or export electricity from and to the grid.

Experience from other countries indicates that as the EV stock increases, it creates pockets of EV concentration, and simultaneous charging of many EVs will create congestion on the distribution grid. Hence, the Active V1G mode must be planned to utilise the existing grid infrastructure fully, and unnecessary system upgrades in the generation, transmission, and distribution systems can be avoided or deferred. VGI offers benefits to all stakeholders, including non-EV uses in terms of reduced power system upgrade costs resulting in lower electricity tariffs.

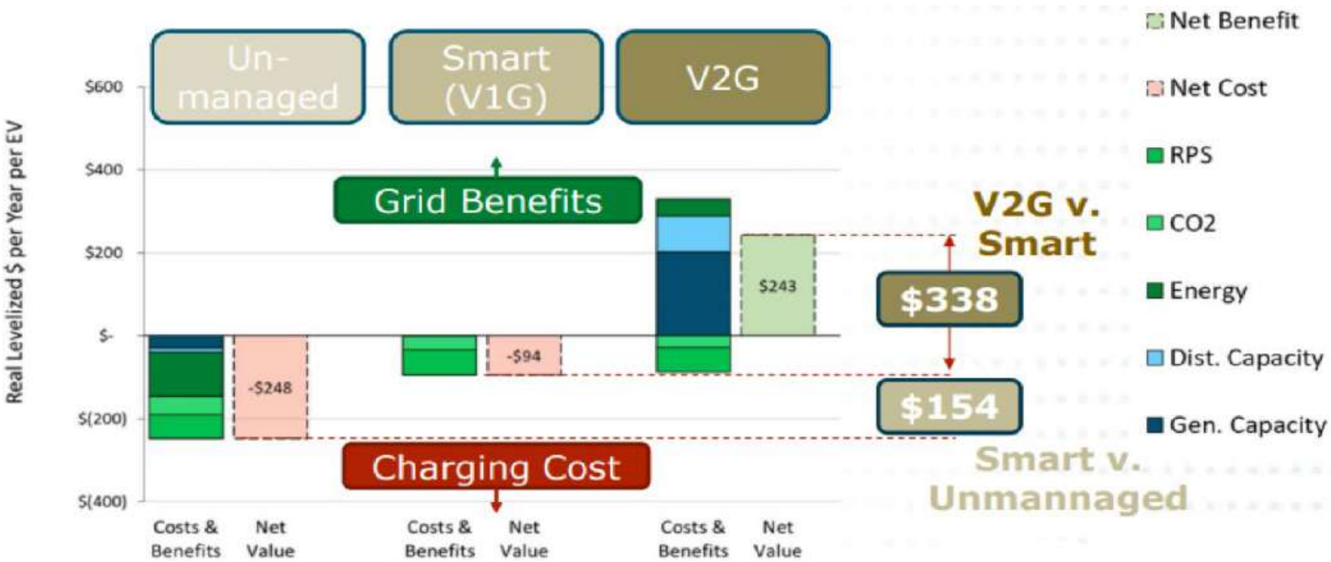
Figure 7-2: V2G demographic

Source: GSEF

The vehicle to grid (V2G) system would allow the electric vehicle to inject power into the grid by discharging its batteries to ensure grid reliability. V2G can be of two types, i.e., on vehicle AC V2G and off vehicle DC V2G. It requires chargers configured with grid integration software, a smart charging controller, and a two-way communication option to exploit its full potential. In addition, vehicle to building (V2B) or vehicle to home (V2H) can also provide flexibility to the grid by providing power to the building or home from the stationary electric vehicle batteries at the time of peak demand. This will open up new potential for distribution utilities in managing the load effectively. With the help of Energy Management System software, it will be easy to maintain both grid and demand-side flexibility.

Although many activities like peak shaving, load leveling, etc. can be achieved through smart charging (V1G). V2G will help EVs act as a generation source and provide additional financial benefits by providing ancillary services and participating in the power market transactions. According to a study by EPRI, V2G offers incremental benefits of USD 338 compared to V1G and USD 492 compared to uncontrolled charging.

Figure 7-3: V2G financial benefits



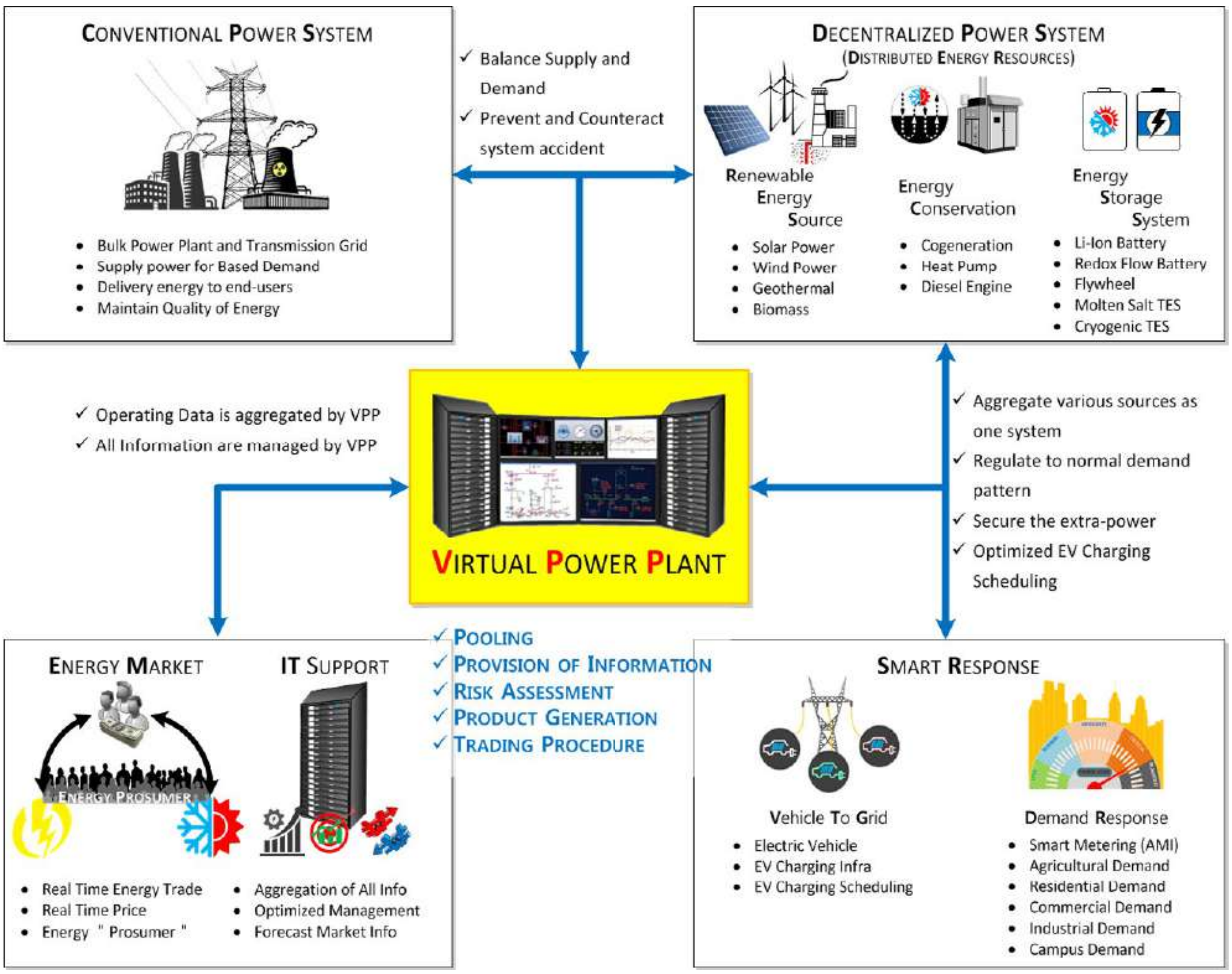
Source: IRENA

However, V2G also impacts battery life, which will be evaluated based on the parameters like battery capacity, level of charging and discharging, temperature, and frequency of charging and discharging. According to IRENA, battery degradation with V2G is limited if the battery stays within a state of charge of around 60-80%.

7.11 EVs as Demand Response (DR) and Virtual Power Plants (VPPs)

Through Vehicle-Grid Integration (VGI) technologies, EVs can provide power back to the grid during short intervals of demand-supply gaps, which will be very useful for grid integration of intermittent renewable energy (RE) resources with the grid. Furthermore, this technology can also support the grid by aggregating large number of EVs connected to the grid as virtual power plants (VPP). The VPP consists of renewable energy resources, battery energy storage system (BESS) and EV batteries, electric vehicle charging stations, demand and response management centres, and smart meters. Figure 7-4 describes a model VPP framework and the actors with their roles in a VPP system.

Figure 7-4: Overall system concept and operational functions of virtual power plant

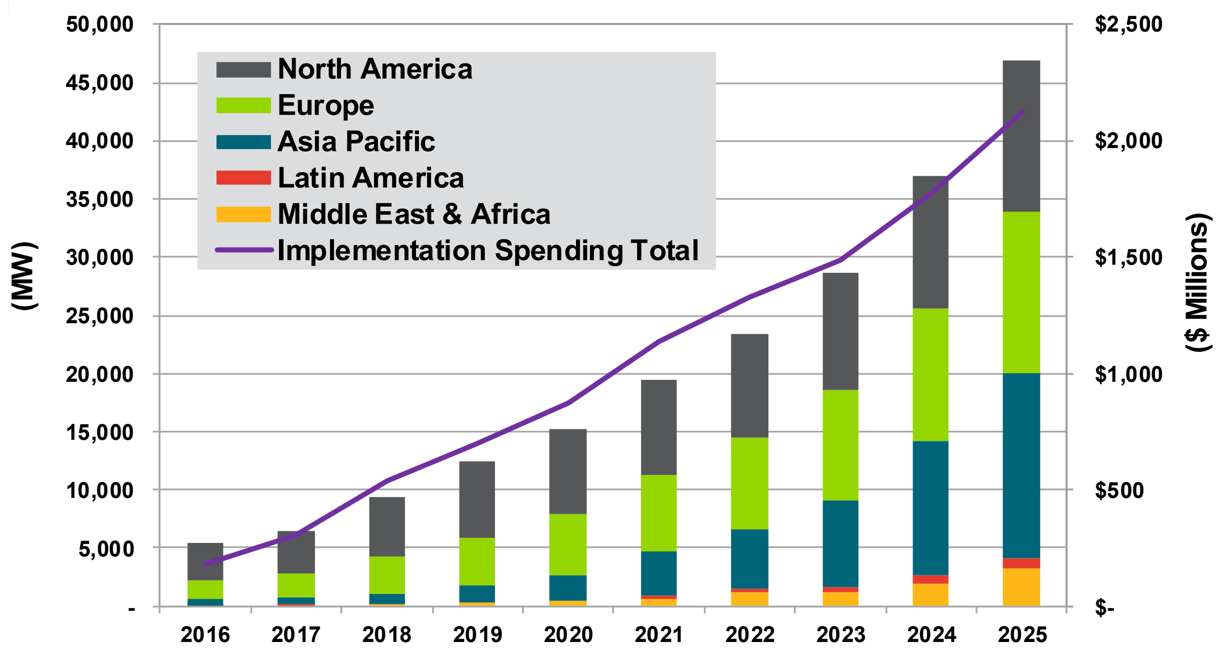


Source: Queen's University Belfast

The advantages of EVs compared to other generation sources in VPP are zero start-up and shut down cost, fast response time, low standby cost, and high availability factor, which can benefit both EV aggregators and the VPP.

The size of the global VPP market may reach 2.1 billion USD/year by 2025. The VPP markets are expected to grow in North America, Europe and Asia as the share of renewables increases in the power systems.

Figure 7-5: VPP capacity and implementation in world markets by year 2016-2025

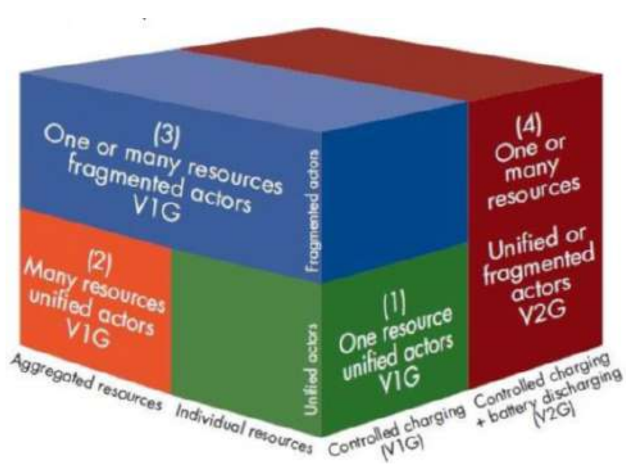


Source: Navigant Research

7.11.1 Feasibility of EVs as Virtual Power Plants (VPPs) through V2G Functionalities

Considering the Government of India's target of more than 30% electric vehicles on the road by 2030 and other targets set by various state governments (like 25% of all new vehicles to be EV by 2024 in Delhi, one million EVs by 2022 in Kerala etc.) it can be envisaged to have approx. 83 million EVs on the road by 2030 (MoRTH, 2017). This growth will have a considerable impact on the grid when connected for charging and proper planning is required on the distribution grid. Adequate policy measures and policy must be mandated to ensure grid reliability and realise the vehicle to grid services such as facilitating RE integration, frequency regulation, etc. The feature of EVs to act as energy storage systems can facilitate utilities in improving their technical, financial and operational efficiency through peak shaving, frequency regulation, acting as operating reserves etc. to maintain power quality and grid reliability. To address these aspects of

According to Rocky Mountain Institute, If FAME II and other measures are successful, India could realize EV sales penetration of 30% of private cars, 70% of commercial cars, 40% of buses and 80% of two and three-wheelers by 2030.



Source: California Vehicle-Grid integration (VGI) roadmap 2014 vehicle grid integration and to ensure grid reliability and power quality, the California Independent System Operator (CAISO) along with the government office, California Public Utilities Commission (CPUC), California Energy Commission and California Air Resources Board, devised a Vehicle Grid Integration (VGI) Roadmap in 2014. This roadmap focuses on determining the VGI value, developing enabling policy and enabling technology development and developed use cases based on three attributes, i.e. benefits to the grid by individual or aggregation of resources, the direction of power flow and alignment of the objective of actors. Considering the above attributes and use cases, the impact of VGI on the distribution grid and its associated value to the stakeholders need to be assessed to figure out the required interventions in terms of policy, technology and standards, business models, coordination among stakeholders, capacity building requirement etc. for minimizing the impact and realizing the full potential of VGI.

7.11.2 Case Study: Grid Integrated Vehicles (GIV) Systems – PJM Demand-Side Resource (DSR) Pilot Project

The Grid Integrated Vehicles (GIV) project undertaken at the University of Delaware; USA has been successfully integrated with the PJM Grid to provide Ancillary Services. This project included several research and development components: analysis of US driving patterns, market for EVs and V2G-capable EVs, development and testing of GIV components (in-car and in-EVSE), interconnect law and policy. In addition, development activities included GIV manufacturing and licensing of technologies etc. Also, five vehicles were built and deployed, four for the fleet of the State of Delaware, plus one for the University of Delaware fleet.

After initiating the V2G concept, experimentations are under continuation in the campus of the University. The EV connected to charging points in the campus participate to the frequency regulation mechanism of PJM. EVs are used with unidirectional or bidirectional power flows. The power flow is changed to follow the frequency variations. In the campus, users are not paid for the service, but they can charge for free. Nuvve is the aggregator that bids its hourly available capacity on the weekly PJM tenders. To reduce the risk of penalties (due to EV availability uncertainty), Nuvve has installed a stationary battery made from ten second life batteries from Chevy Volt (220 kWh in total).

Figure 7-6: UD PJM demand side resource pilot project

Source: University of Delaware

7.12 Identification of V2G Compliant EVSE for BESCOM

Presently in India there are no EVs that are offering V2G services. BESCOM shall start with Time of Use (ToU) tariffs for EV charging through direct messaging's to EV Owners to motivate them to charge during off-peak hours. This may be followed by remote switching-on and switching-off of EVSEs at customer's premises by networking the EVSEs.

ISGF is advocating for V2G capabilities in AC Type2 chargers in India and working with BIS to include this in the BIS standards.

BESCOM is promoting public charging stations where EVs can charge. V2G is possible where vehicles are connected to the EVSE for long hours such as homes, office complexes, schools/colleges etc. BESCOM may promote V2G by offering incentives to EVs participating in V2G. Many EVs connected to the grid can be aggregated as virtual power plants (VPP). A detailed explanation of VPPs is presented in Section 7.11 of the report. EVs and EVSEs capable of V2G are not presently available in India. This is an emerging area which may take 3-5 years to be rolled out in India.

BESCOM should watch this technology as it matures and is available in India. Regulatory support for V2G may be required when BESCOM will be ready for offering V2G services.

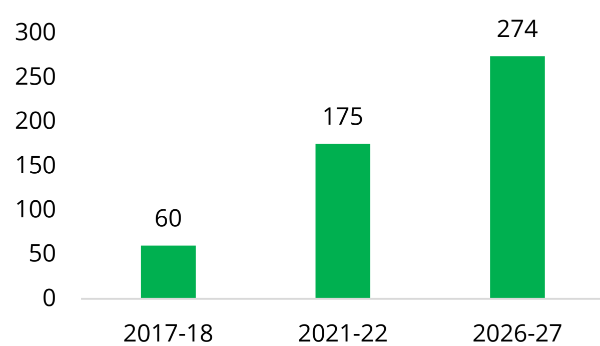
7.13 Leveraging EVs to Store Surplus Power from RE and Feedback to the Grid During Peak Hours

The vehicle-to-grid (V2G) technology makes it possible to store the surplus electricity generated from renewable energy sources (solar and wind) to charge EV batteries during non-peak periods, and feed power back to the grid when needed, enhancing grid stability and reducing electricity costs at peak hours.

7.13.1 Utilization of EVs for better RE Grid Integration

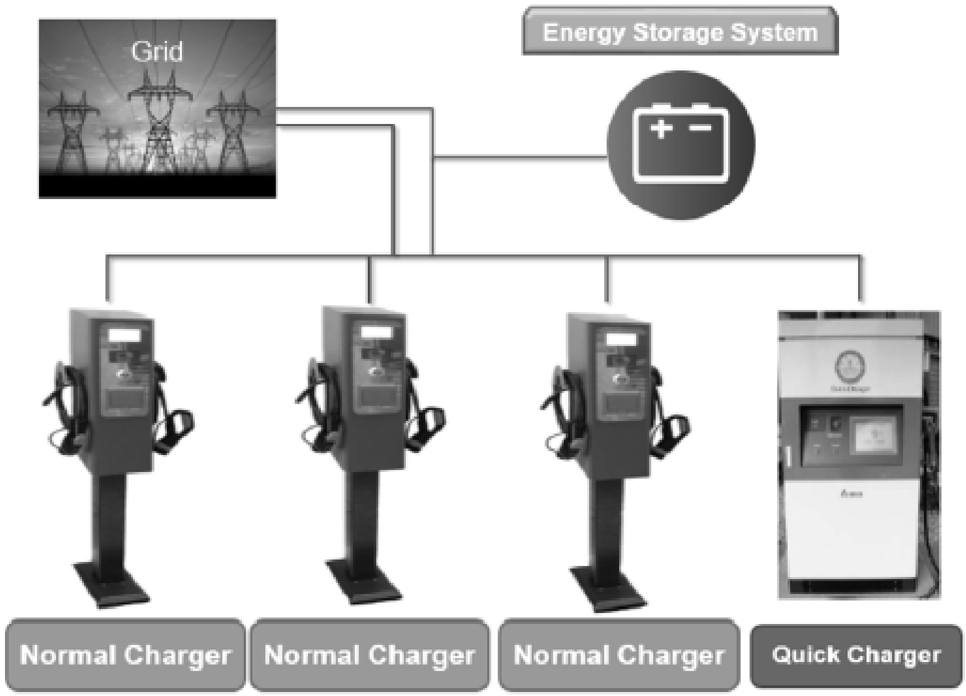
The government of India vowed to add 175 GW of renewable energy (of which 100 GW is solar) to the grid by 2022. However, with a larger share of renewables being intermittent, sudden drop in generation can lead to grid imbalances. Hence, utilities need to engage more actively in balancing the grid by identifying new opportunities/ technologies to addresses these issues. For example utilities can deploy energy storage devices to reduce duck curve in case of higher solar penetration. The study outcomes suggest EVCS should be integrated into the feeder with rooftop solar as EV energy consumption is encouraged during the periods of high-RES power production to avoid overvoltage and congestion in the grid and also can offset the intermittency of RE in the grid to ensure grid stability.

Renewable Energy Target in GW in India



Source: MoP

Figure 7-7: Charging system model



Source: IEEE 2019

Table 7-10 presents the ESS requirement for medium voltage (MV)/low voltage (LV) grid support based on estimated penetration of solar PV (both ground-mounted and rooftop) likely to be connected to the MV and LV grid.

Table 7-10: Energy storage estimations for MV/LV Grid (MWh)

Estimates	2019	2022	2027	2032
Generation (GW)				
Thermal	209	NA	NA	NA
Hydro	43	NA	NA	NA
Nuclear	6	NA	NA	NA
Solar	26	107	244	349
Ground Mounted Solar	24	68	148	206
SRTPV	1.5	40	98	144
Connected to EHV	14	34	66	94
Connected to MV	11	35	84	112
Connected to LV	2	40	98	144
Wind	35	NA	NA	NA
Small Hydro	4.5	NA	NA	NA
Biomass & Biopower	10	NA	NA	NA

Estimates	2019	2022	2027	2032
Peak Load (GW)	**192**	**333**	**479**	**658**
Energy (BUs)				
Annual Energy Requirements	**1192**	**1905**	**2710**	**3710**
Storage Recommended (MWh)				
Battery for LV Grid	**241**	**5908**	**14617**	**21484**
Battery for MV Grid	**1054**	**3482**	**8393**	**11191**
Total Storage (MWh)	**1295**	**9390**	**23010**	**32675**
Approximate (GWh)	1 GWh	10 GWh	24 GWh	33 GWh

Source: ISGF

Peak Load and Annual Energy Requirements are taken from CEA Estimates (18th Electric Power Survey). In congruence with the RE target of 175 GW by 2022, the calculations are based on the 100 GW Solar, out of which 40 GW is SRTPV, 20 GW is medium size installations and 40 GW is from large solar parks. Similarly, for 2027 and 2032, the ratio of SRTPV were taken in accordance with the 2022 targets constituting of 40% SRTPV of the total solar installed capacity. All the values for 2027 and 2032 have been forecasted using the best available data in the public domain.

7.13.2 Assessment of Deploying EV Batteries for Smoothening of SRTPV Output through V2G

The use of energy from a SRTPV system for charging EVs is environmentally advantageous and a better approach towards green mobility. Further, suppose solar energy is generated in close proximity to the EV charging points. In that case, it results in lower transmission losses and helps mitigate the effects of a sudden rise in EV demand on the grid.

The government of Karnataka has set ambitious targets for both SRTPV and EVs in the coming years. In this context, it is important to identify and assess the options for wide-scale deployment of a system that ensures SRTPV and EV charging.

Whenever there is peak demand, the battery can be utilized to feed the grid, and all EVs being connected to the grid will discharge their battery and it will be fed into reverse direction to meet the demand response of the grid. Whenever there is a high solar generation typically between 10 am to 4 pm, can be utilized to recharge batteries by applying different incentive mechanism.

Energy Storage Systems (ESS) can help in peak load shaving and load shifting. The impact of ESS on 11kV feeders were studied and results presented in the ISGF's Energy Storage Systems Roadmap for India[17]. In this study, it was observed that SRTPV injection to the grid with EVCS can improve the feeder's voltage profiles; but higher share of SRTPV injection could cause harmonics that need to be monitored.

Case Study: DRIVECO PARASOL, France

DRIVECO has created a cutting-edge technological innovation called the PARASOL, which is a 100% solar-powered charging station for electric vehicles. It is compatible with all electric vehicles in the market and can charge eight cars simultaneously. The PARASOL produces its own energy using the 29 kW PV rooftop on the carport, stores in its batteries and delivers it to all 70kW charging points.

[17] *https://indiasmartgrid.org/report_register.php?report_id=98*

Figure 7-8: SRTPV powered charging station

Source: DRIVECO

The above Figure shows all the components, including EV chargers, solar panels, and battery storage in a single charging station. This scheme reduces the overall cost of the charging station.

This integrated solar PV cum battery storage charging station can operate in four different modes is explained below (as shown in Figure 7-9).

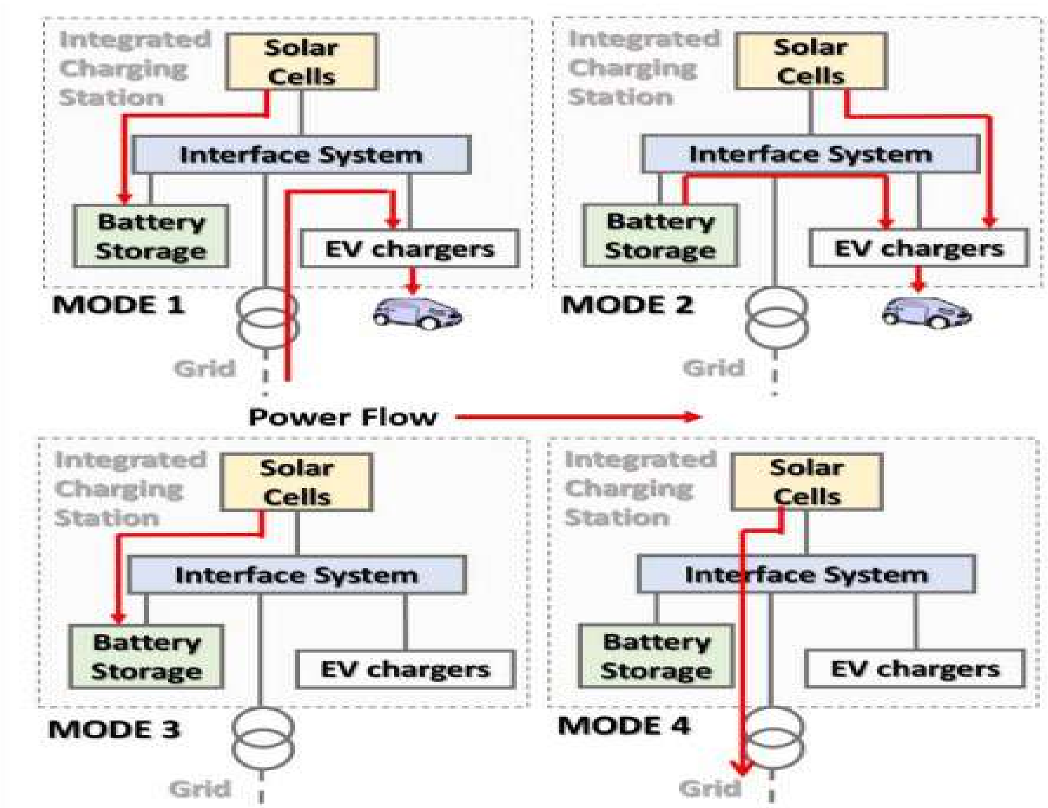
Mode 1: Solar energy is directly fed to the battery storage, and EV chargers draw the power from the electricity grid. Battery storage provides backup for the grid and also helps to manage peak load.

Mode 2: EV chargers draw the power directly from solar cells and battery storage. At the time of peak load or power failures, battery can be utilized for EV charging.

Mode 3: Using solar energy, battery charging is done, and EV chargers draw power from battery backup, which is also connected to the grid.

Mode 4: Solar energy is directly fed into the grid, and EV chargers draw power from the electricity grid. Here battery charging is done by the electricity grid and used as power backup.

Figure 7-9: Different modes of integrated EV charging station

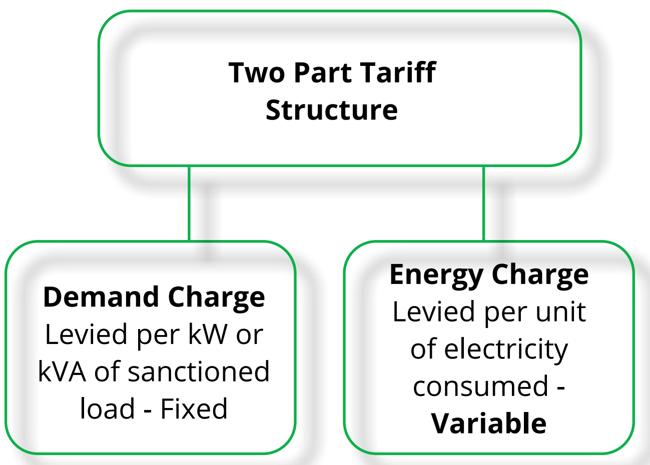


Source: IEEE 2017

8 TARIFF RATES FOR EV CHARGING AND REGULATIONS

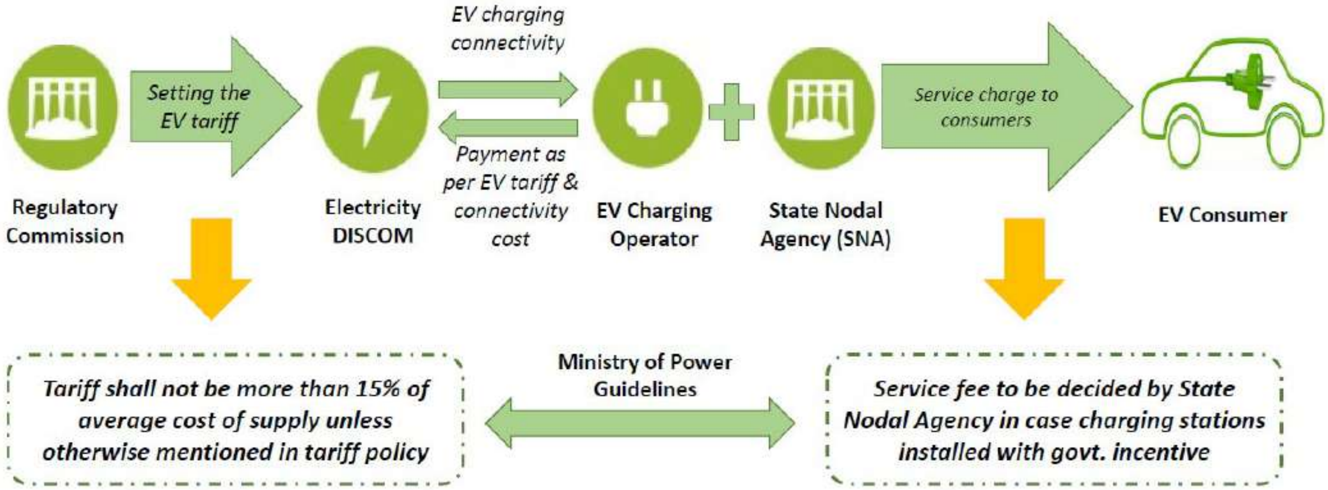
8.1 Electricity Tariff for Electric Vehicle Charging in the Various States in India

Several Indian states have issued EV policies and electricity tariffs for EV charging. In 2019, ISGF did a study to compare the EV policies and electricity tariffs for EV charging in different states in India and presented global EV promotion initiatives[18]. The study also suggested specific policy improvements Indian states can make to ensure the successful adoption of EVs.



[18] *India Smart Grid Forum*
https://bit.ly/3svRsDp

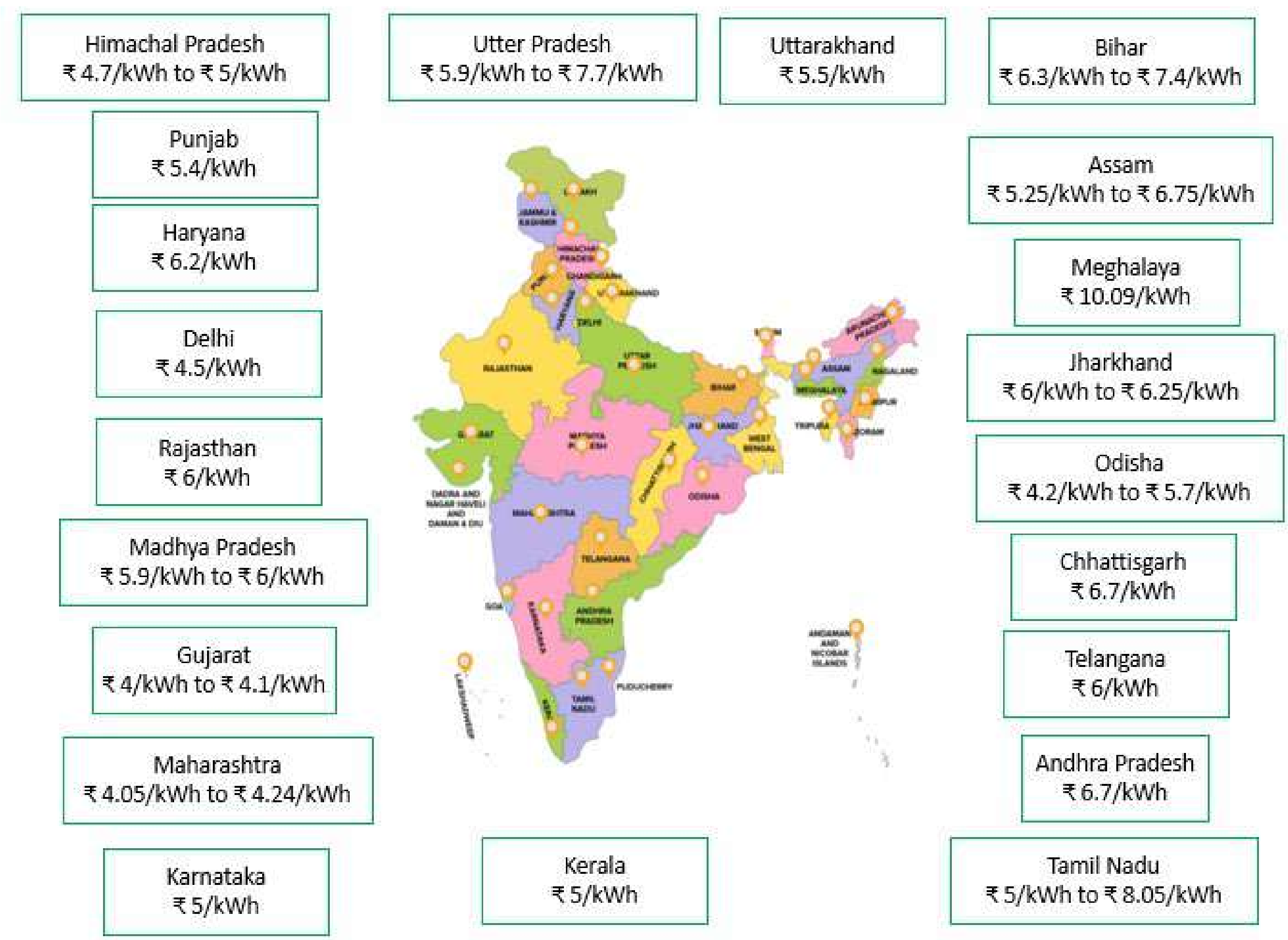
Figure 8-1: EV tariff Eco-system in India



Source: ISGF

Following a presentation by ISGF at the Forum of Regulators (FOR) Meeting in December 2016 arguing for a separate tariff slab for EV charging, for the first time in the country, Delhi Electricity Regulatory Commission (DERC) in its tariff order introduced a separate tariff for EV charging in 2017 which is substantially lower than the commercial tariff INR 5/kWh for charging from HT supply and INR 5.5/kWh for charging from LT supply. Also, there are no minimum monthly charges for capacity. This was intentionally kept lower to promote EV rollout and the creation of the EVSE ecosystem. In 2018, Karnataka and Maharashtra State Electricity Regulatory Commissions introduced separate tariffs for EVs while DERC reduced the tariffs in 2018-19. As of June 2021, twenty one states have issued electricity tariffs for EV charging in India. While Delhi, Punjab, Andhra Pradesh, Uttar Pradesh, Telangana, Chhattisgarh and Madhya Pradesh have refrained from adding fixed charges component to their EV tariffs, Maharashtra, Jharkhand, Haryana, Karnataka, Gujarat and Chandigarh have kept fixed capacity charges. In addition, Delhi, Maharashtra, Uttar Pradesh and Telangana have applied "Time-of-Day" (ToD) rebate/surcharge as part of their EV tariffs as a means to influence EV charging behaviour. The below Figure represents EV tariffs of various states in India.

Figure 8-2: Tariff structure for the various states in India



Source: State Regulatory Commissions

8.1.1 Highlights of EV Charging Tariff

- LT energy charge varies from INR 4.1/kWh in Gujarat to INR 7.7/kWh in Uttar Pradesh
- States like Gujarat, Haryana, Karnataka, Maharashtra etc. have announced demand charges for EV charging stations
- States like Andhra Pradesh, Chhattisgarh, Delhi, Punjab, Telangana waived off demand charges to boost EV adoption
- Bihar has the same tariff for EV as the respective consumer category rate
- Utter Pradesh has a ToD tariff with surcharge and rebate at 15%
- In Delhi, ToD is applicable for three-phase consumers with load >=10 kW/kVA with surcharge and rebate at 20%
- Maharashtra ToD tariff:
  - o Surcharge (INR 0.80/kWh for usage from 09:00hrs to 10:00 hrs and INR 1.1/kWh from 18:00 hrs to 22:00 hrs)
  - o Rebate (INR 1.50/kWh for usage between 22.00 hrs to 06.00 hrs)

8.2 Electricity Tariff for Electric Vehicle Charging in Karnataka State

ISGF has always advocated that there should not be a fixed charge for EVSEs for the first 5 years. The fixed charges can be waived off, which will improve the ROI of EVCS and encourage private investors to set up EVCS in the country.

As per the study's evaluation of BESCOM's EV Charging Station business, the net revenue generated is still negative. The imposition of fixed charges will slow down the entire process. For the installation of 1000 EVCS in Karnataka, bringing in private investors will be difficult because of poor ROI. Removing the fixed charges will offer some relief for EVCS investors. BESCOM should file a petition to KERC to waive off the fixed charges.

Table 8-1: Energy storage estimations for MV/LV Grid (MWh)

Fixed/ Demand Charges per kW	LT	HT
	INR 70 /kW/month	INR 200 /kVA/month
Energy charges per kWh (For both LT and HT)	INR 5/kWh	

Source: BESCOM

8.3 Key Factors for Setting up of EV Tariff

Tariff setting is a dynamic work in India, and the tariff environment varies widely from state to state. EV charging is different from other groups of customers, and distribution utilities and regulators are trying to evaluate the demand features of this category. Some states have already revised the EV tariff structure within one year of implementing separate EV charging tariffs. There are three main characteristics of EV charging that make EV a unique user class:

Mobile source of electricity requirement: EVs are mobile, and while their charging points are stationary, depending on different factors such as charging technology, EV battery capacity and C-rate, EV usage, etc., the energy and power requirements at the charging locations might vary widely.

Uneven load: With spikes in the demand curve, EV charging loads at charging points are unpredictable. It could have a severe impact on the distribution network, especially on power analysis. In the case of fast charging of EVs with big batteries, this is more likely to happen.

Bi-directional energy flow: EVs can be leveraged using Vehicle-to-Grid (V2G) features as Distributed Energy Resource (DER). Vehicle-Grid Integration with bi-directional energy flow due to batteries and, thus, EVs can theoretically serve as prosumers. However, appropriate metering and tariff setting will be required to allow the application of EVs as a virtual power plant (VPP).

8.4 Cost of Grid Upgrade for EVCS

In most parts of India, the DT and overhead wire/underground cables are generally overloaded. When many EVs are connected to the low voltage lines from one particular DT, the DT might burn. Initial trials with EVs in almost all geographies have experienced the creation of pockets of EV concentration where grid equipment needed upgrade. ISGF study in Kolkata in 2016-17 noticed that 8 months in a year (except November to February when air conditioners are seldom used) the existing DTs might not accommodate DC fast chargers. If the grid upgrade cost, which will run into millions of rupees, is passed on to the EVSE establishment, the cost of electricity will be high so that e-Mobility will not take off.

Instead, ISGF has been advocating that the benefits of e-mobility (such as reduced air and noise pollution, fatigue less travel in air-conditioned electric buses, etc.) are available to the entire population in a city. Hence, grid upgrades for accommodating EVSE should be part of the annual CAPEX of BESCOM.

8.4.1 Land for EVSE

EVSE itself require little space and can even be wall-mounted. But the EVs that will be connected to the EVSE require parking space for several minutes/hours. The land for the same can be expensive in cities. Even if a small rent is levied for the same by municipalities or property owners (Malls, Hospitals, Campuses, Railway Stations, Bus Stands, Airports, and Office Complexes etc), the EVSE business will be unviable. Therefore, ISGF suggests that BESCOM should appeal to the State Government to reserve 20% of parking spaces for EVs without any lease rent where EVSEs can be installed.

8.5 Connection Charges

Table 8-2: Infrastructure cost for EV connection

Sl No	Capacity	Description	Cost in INR
1	Up to 50 kW	For laying of 0.5 km length of 11 kV, 3x95 Sqmm XLPE UG cable using conventional laying with the excavation of soil	6,01,939
		Erection of 3 phase, 11kV/433V, 63 kVA BEE – 4/5 star rated distribution transformer centre using 9 Mtr RCC pole DPTS	2,03,056
		Cable testing charges	20,000
		Total infrastructure cost	8,24,995
2	50 kW to 100 kW	Providing compact RMU 11 kV class SF6/VCB type (1 Incomer +1 Breaker + 1 Outgoing)	4,46,176
		For laying of 0.5 km length of 11 kV, 3x95 Sqmm XLPE UG cable using conventional laying with the excavation of soil	6,01,939
		11 kV HT metering cubicle of different CT ratio, both side cable entry type with 3 CT & 3 PT, with transparent cover TTB, copper busbar, modem & 2 no of meters for 3 phase 4 wire metering without load break switch (HT metering box fabricated out of 3 mm MS sheet duly epoxy powder coated) as per revised specification (Dwg No. BESCOM/GM/QS&S/.... Dtd 24.11.2018)	1,88,292
		Erection of 3 phase, 11kV/433V, 250 kVA 4/5 Star rated distribution transformer centre using 9 Mtr RCC pole DPTS	2,46,426
		Cable testing charges	20,000
		Total infrastructure cost	15,02,833
3	100 kW to 200 kW	Providing compact RMU 11 kV class SF6/VCB type (1 Incomer +1 Breaker + 1 Outgoing)	4,46,176
		For laying of 0.5 km length of 11 kV, 3x95 Sqmm XLPE UG cable using conventional laying with the excavation of soil	6,01,939
		11 kV HT metering cubicle of different CT ratio, both side cable entry type with 3 CT & 3 PT, with transparent cover TTB, copper busbar, modem & 2 no of meters for 3 phase 4 wire metering without load break switch (HT metering box fabricated out of 3 mm MS sheet duly epoxy powder coated) as per revised specification (Dwg No. BESCOM/GM/QS&S/.... Dtd 24.11.2018)	1,88,292
		Erection of 3 phase, 11kV/433V, 250 kVA 4/5 Star rated distribution transformer centre using 9 Mtr RCC pole DPTS	4,90,562
		Cable testing charges	4,90,562
		Total infrastructure cost	17,46,969

Source: BESCOM

9 UTILIZATION OF EXISTING FUEL RE-FILLING STATIONS FOR EV CHARGING STATIONS

India has over 61,000 fuel refilling stations, of which about 3,300 are in Karnataka State. As these fuel stations have been built in convenient locations for motorists in the region over decades and the motorists are aware of the locations of the fuel stations, there is an urge to examine the feasibility of utilizing the existing fueling station for electric vehicle charging. This will have both advantages and disadvantages, which are examined in detail in the following sections.

9.1 Space and Power Availability

An EV (typical car) requires 50 square feet (5’X10’) space for parking at the charging station. The time an EV takes to charge depends on the battery capacity, C-rate, charger output and the state of charge (SoC)[19] of the battery when the car come to the charging station. The popular EVSEs and their power output capacities and voltage levels are given in the Table 9-1.

[19]State of Charge (SoC) is the amount (percentage) of charge left in the battery. If the SoC of the battery is 30% when the EV comes to charge, the top-up of 70% will make the battery fully charged.

Table 9-1: EVSEs, power output capacities and voltage levels

EVSE Type	Capacity (Output kW)	Voltage Levels (V)
Bharat Charger AC001	9.9	230
Bharat Charger DC001	15	48 – 85
AC Type 2	7.5 /22	415
CCS2	25 /50	200 – 500
CCS2	150	200 – 1000
CCS2	250	200 – 1000
CHAdeMO	25	200 – 500
CHAdeMO	50	200 – 500
CHAdeMO	150	200 – 500
Tesla Super Charger	100	200 – 1000
Tesla Super Charger	250	200 - 1000

Most EVs in India have batteries with 0.3C or 0.5C charging rate. So, it takes several hours to charge, irrespective of the capacity of the charger. In a typical fuel station in the city, there is limited space to keep the cars parked for long hours for charging.

Normal fuel stations in cities have 15 kW power connections. Out of which, 10 kW has used the fuel dispensing machines. So, in most cases only one AC 001 EVSE of 3.3 kW can be installed in a fuel station without a new power connection.

CHAdeMO, CCS2 and DC 001 chargers operating at voltage level below 500 V its may be installed at fuel stations subject to space availability for parking EVs and feasibility of new power connection. Fuel stations can also have EVSEs and battery swapping stations for 2-wheelers and 3-wheelers.

9.2 Regulatory Approvals

Fuel stations in India must follow the safety regulations issued by the Petroleum and Explosive Safety Organization (PESO). The PESO norms relate to fuel tank size and location, boundary walls, distance between machines termed "pump islands", underground storage tanks, entry and exit to avoid traffic congestions etc. For example, there should be a distance of 6 meters between the boundary wall and dispensing machines and every fuel station before going operational needs to get an approval of PESO.

For installing EVSEs in fuel stations, the detailed plan and drawings must be submitted to PESO for approval. PESO is the only regulatory compliance that is required to install a charging point at any fuel station.

PESO regulations do not permit electrical connections/equipment operating above 430 Volts. Which require modifications as all the fast chargers of 150 kW to 500 kW capacities operate at 500 to 800 V.

9.3 EVSE Deployments in Fuel Stations

EVSEs have been installed in many fuel stations in few states in India, mostly in Indian Oil's fuel stations.

Figure 9-1: EV charging station at a fuel station

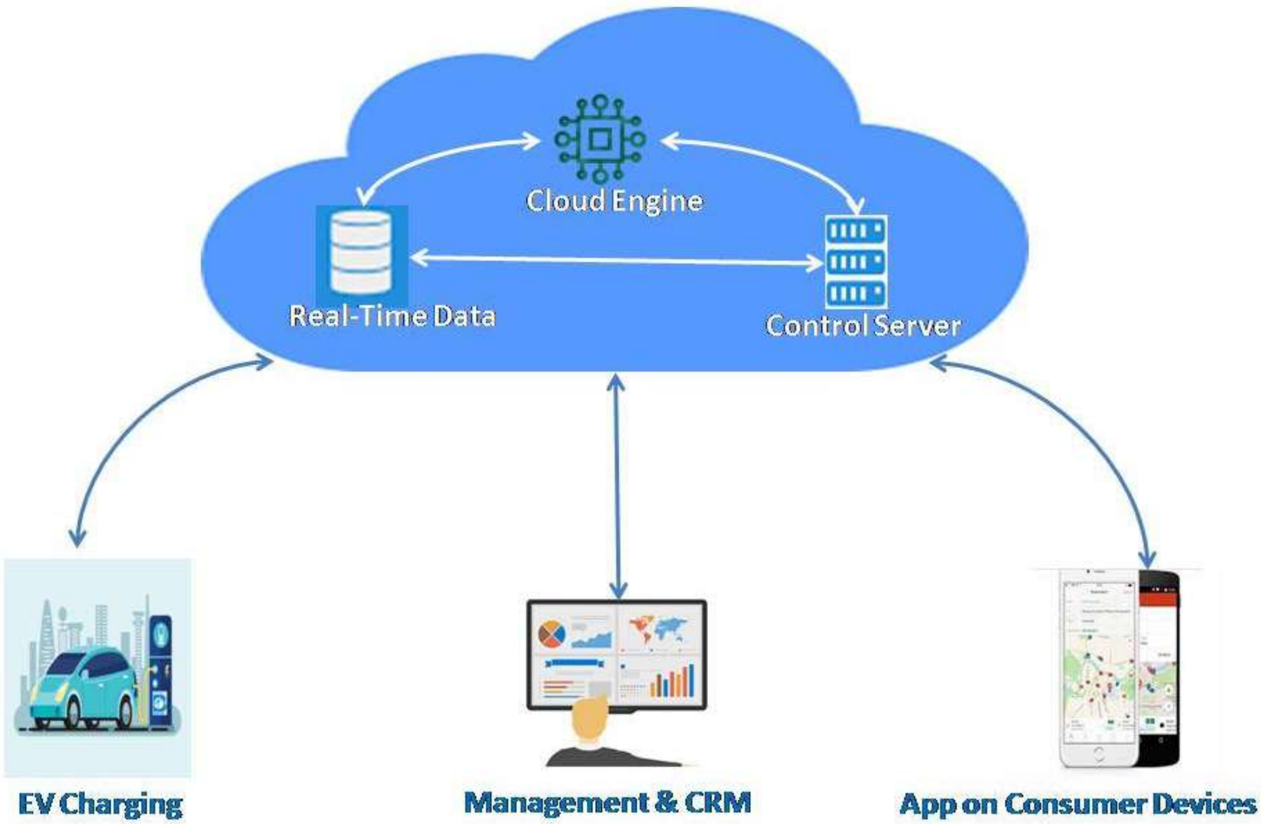
9.4 Way Forward

The fuel stations on highways have larger spaces where several EVs can be accommodated simultaneously for charging. Such fuel stations can create an EV charging zone separated by a boundary wall where high-capacity power connection can be taken and high-power DC fast chargers can be installed. The procedures related to new electricity connections allotted by DISCOMs need to be streamlined across the country to fast track the EVSE rollouts.

10 SOFTWARE REQUIREMENTS FOR EV CHARGING STATIONS

For efficient operations of EV Charging Stations (EVCS), software solutions are necessary. Ideal software platform connects all key stakeholders including OEMs, Utilities, EV owner/driver, charging points/stations owner/ aggregator to administer the eco-system with the help of a web portal. It is a cloud-based solution integrating each charging station with wired or wireless public internet or private network. It collects charging data from the charging station for billing and generates invoices for the same. It also helps the EV driver locate the nearest EVCS and schedule/book to charge the EV at a particular time slot subject to availability.

Figure 10-1: Software platform for EV charging



10.1 EVCS Management Software Functionalities

EV charging software solutions should have the following systems or functionalities[20] for different purposes.

10.1.1 Billing and Invoicing System

- The billing platform should generate real-time consumption-based invoices based on the energy consumption data shared by the charging station to the cloud server
- Each transaction shall be issued with an invoice in digital form. Invoice details with a unique invoice ID should be shared on the Mobil App, E-mail, SMS, etc.
- The charging station operator should be able to generate a daily report to evaluate charging station business performance
- DISCOM shall be able to announce price and discount on energy consumption by end-users (ToU or ToD shall be pre-configurable)
- Outlet based dynamic pricing based on fixed time periods/ frequencies shall be provisioned for the purpose of Retail Price Management
- Tax rules should be customizable in billing invoice
- Sales dashboards to track sales and billing statistics for B2B, B2C shall be available in the billing system

[20]EVCS Solution providers: https://bit.ly/3piJnjw, https://bit.ly/3t3sGeq, https://bit.ly/2NGE53x, https://bit.ly/3a5MKUK, https://bit.ly/3pmZf4p, https://bit.ly/3t0cM4l

10.1.2 Device Management

- The EVSE shall be remotely enabled and disabled; while disabled, it will be masked from the available charging point/station lists on a GIS map
- Based on availability and usage, a heat map shall be available to provide an update to the utility and network service providers
- Device firmware shall be upgradable over the air (OTA)
- A self-diagnostic module shall be provided for the health and status monitoring of EVSE
- Public Key Infrastructure (PKI) based security mechanism shall be implemented
- EVSE shall support standard communication protocol to ensure interoperability

10.1.3 Service Management

- A new EVSE shall be added with necessary permissions to the system
- Service price shall be updated and managed as per requirement
- Service price shall be configured universally and should be customizable for each charging station
- EVSE location should be marked on the GIS map for easy user navigation
- Heat map of EVSE/ charging stations shall be available to utilities for load management
- A provision of discount and price management shall be available
- API shall be available for third-party integration
- Premium services should be configurable separately

10.1.4 System Management

- System generated alarm, event notifications; performance issues with maintenance reminders shall be available to designated officers or individuals
- A provision of auto escalation-based rules setting shall be available
- Service operation management with remote authorization shall be provisioned to turn on/off the system remotely, especially at the time of maintenance

10.1.5 Digital Payment

- Digital payment system shall be adopted for cashless transactions
- Custom wallet system shall check balance availability and enable charging limit accordingly
- The wallet should be integrated with the National Payment Corporation of India Limited gateway for UPI enabled payment system
- The wallet should be integrated with Master Card and Visa (both credit and debit cards) payment gateway for currency recharge
- Transaction history shall be available to the consumers and EVSE operators

10.1.6 Dashboard and Reporting

- Usage and revenue dashboard shall be available for EVSE operators
- Charging station daily/weekly or monthly reports shall be available
- Automated report generation based on selectable KPIs shall be available
- Rule-based report generation shall be available

- There should a provision for optional data analytics module integration with existing system
- Consolidated regional dashboard/reports shall be provisioned for the DISCOM
- Substation wise charging station reports shall be available for DISCOM
- Charging history report shall be available to users

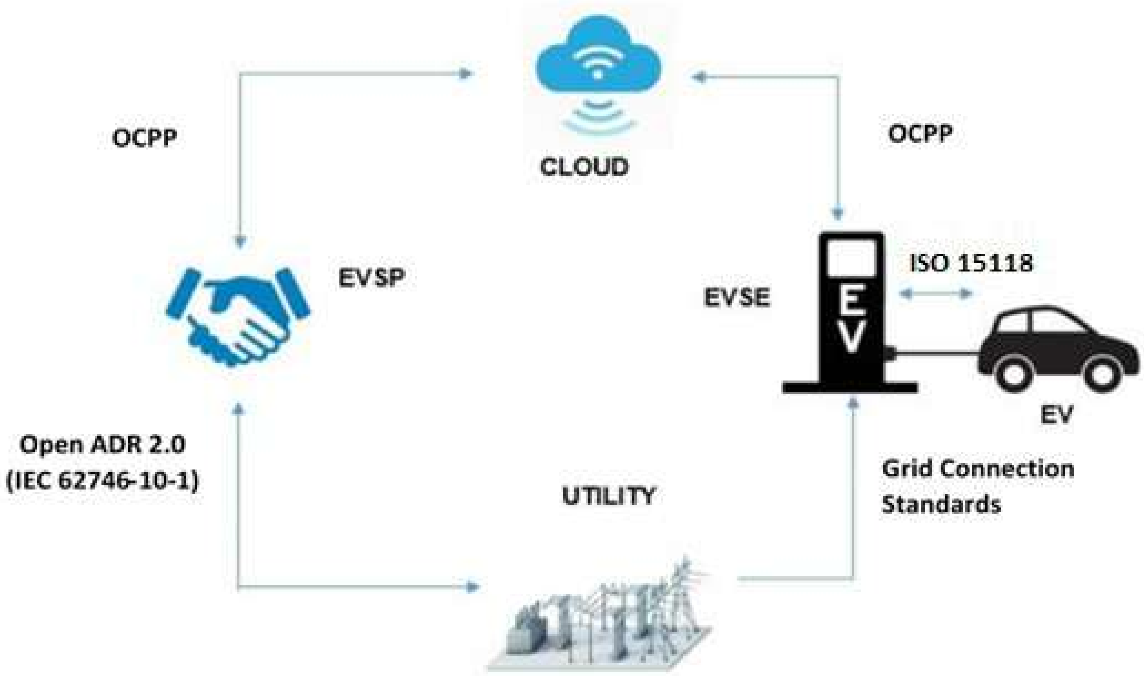
10.1.7 Mobile Application

- End user/EV owners shall be given following facilities through a mobile application:
  - i. GIS navigation of locating the nearest (and available) charging stations
  - ii. Real time pricing for energy consumption
  - iii. Online billing and payment
  - iv. User creation and profile management
  - v. Basic CRM
  - vi. Wallet
- Charging station operator shall be given following facilities through mobile application:
  - i. Notifications based on the charging station alarm/alerts
  - ii. Payment reconciliation and daily report
  - iii. Utility consumption report
  - iv. Profit /Loss report (optional)
- DISCOMs shall be given following facilities through mobile application:
  - i. Access to the authorized charging stations
  - ii. Electricity consumption reports
  - iii. Usage and system alert notification
  - iv. Remote monitoring and control for charging station functionalities

10.2 Communication Protocols for EVSE Management

EV charging requires secure communication between various mobility and energy entities. Communication protocols provide rules to facilitate the communication and data exchange between various entities to exchange data between them successfully. Standards-based protocols will ensure seamless communication amongst the key stakeholders. Proprietary protocols would limit the interoperability and grid integration of EVSEs. Several standards are available for communication between different stakeholders that are published by the IEC, IEEE, and ISO. Open Charge Point Protocol (OCPP) is a defacto standard adopted in the EV domain.

Figure 10-2: Electric grid communications protocol

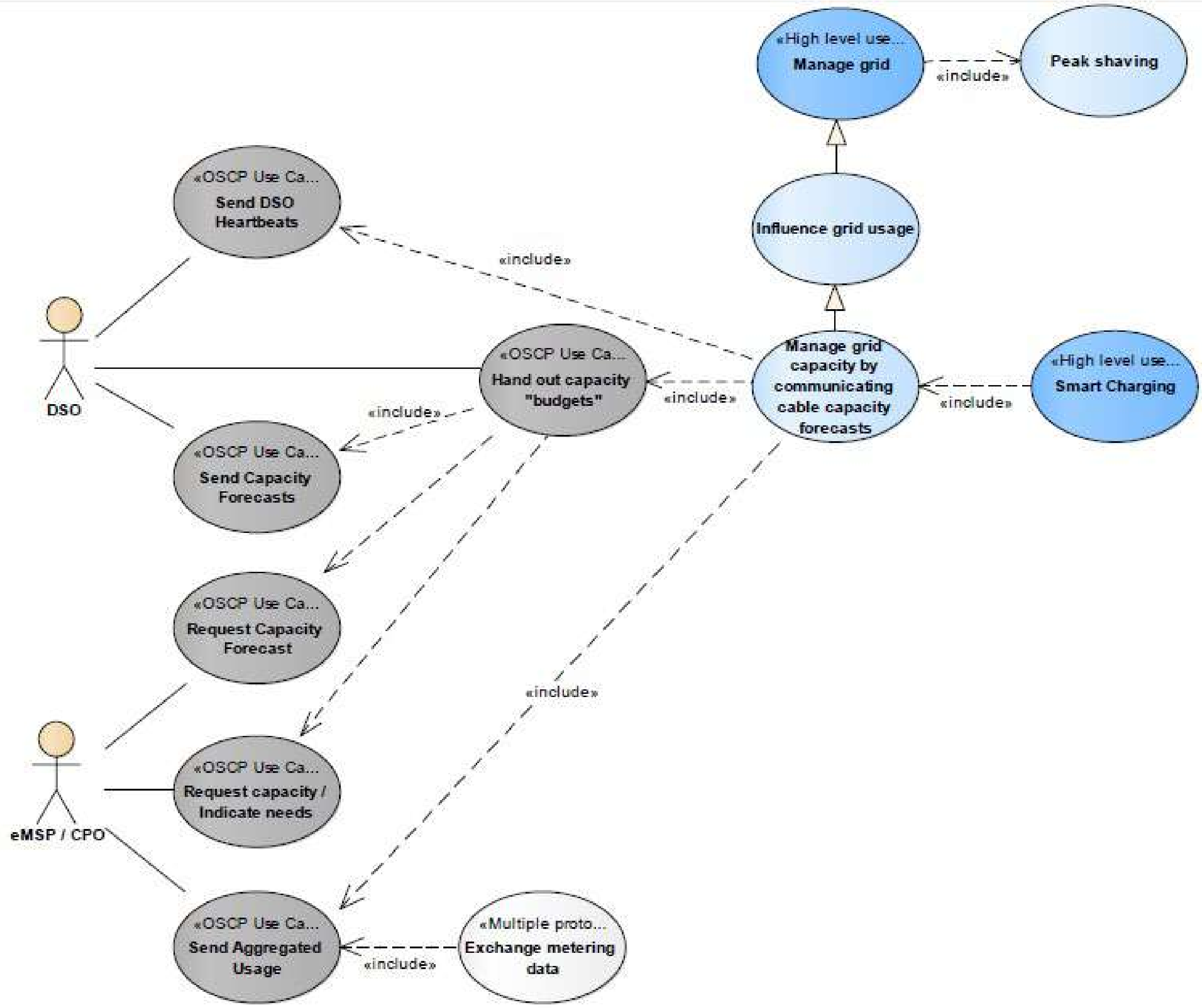


Source: ISGF

10.2.1 Open Smart Charging Protocol (OSCP)

The OSCP was originally designed for communicating a prediction of the local available capacity to charging station operators to enable them to fit the charging profiles of the EVs within the boundaries of the available capacity. The new version OSCP 2.0, describes use cases in which the messages are applied in more generic terms than OSCP 1.0, aimed explicitly at smart charging of electric vehicles by a DISCOM. This is driven by the integration of EVs in larger energy ecosystems, including PV, stationary batteries, heat pumps and other devices. Figure 10-3 illustrates the use cases that OSCP supports. The use cases supported by OSCP are currently quite specific for the scenario where a DISCOM manages grid capacity by distributing capacity forecasts, i.e., to either e-Mobility service providers or Charge Point Operators.

Figure 10-3: Use case overview of OSCP protocol

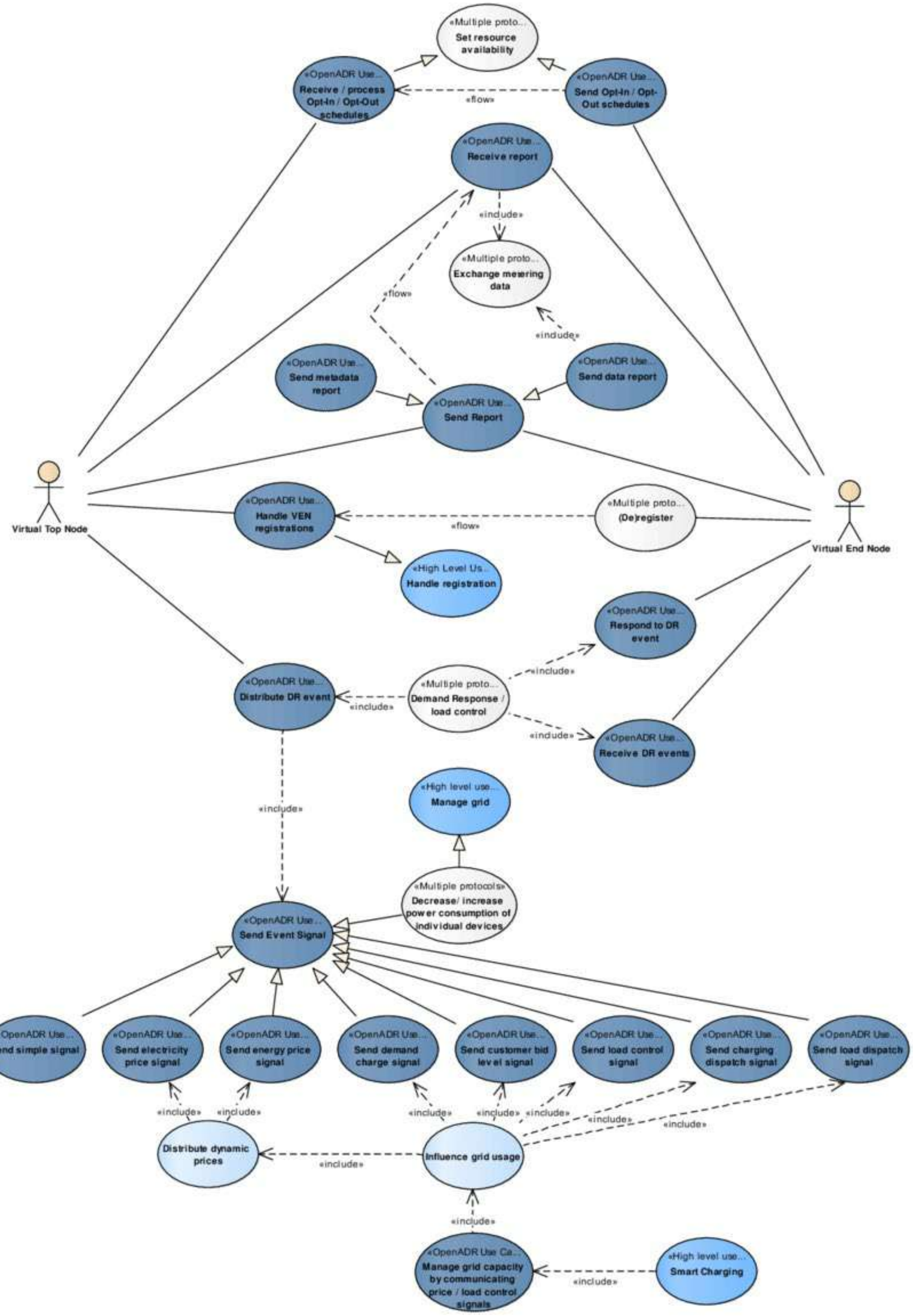


Source: ElaadNL

10.2.2 OpenADR 2.0 / IEC 62746-10-1

OpenADR is a communication protocol originally developed by companies and industry stakeholders for Demand Response (DR) from power system operators or electric utilities to the electric customers. OpenADR includes both a web-based architecture and protocol as well as a data model to communicate price signals to reflect load demand requests, such as for peak shaving or emergency congestion management. These pricing signals can then be used by building and industrial control systems to respond appropriately with reductions (or even increases) in loads. OpenADR 2.0b has been accepted by the IEC as IEC 62746-10-1 and can be secured using web security TLS and PKI techniques. Some efforts have been made to broaden the use of OpenADR to other purposes, such as monitoring and control of DERs, but such changes would require major changes to the OpenADR specification. Figure 10-4 illustrates the use cases that are supported by OpenADR 2.0.

Figure 10-4: Use case overview of OpenADR 2.0 standard



Source: ElaadNL

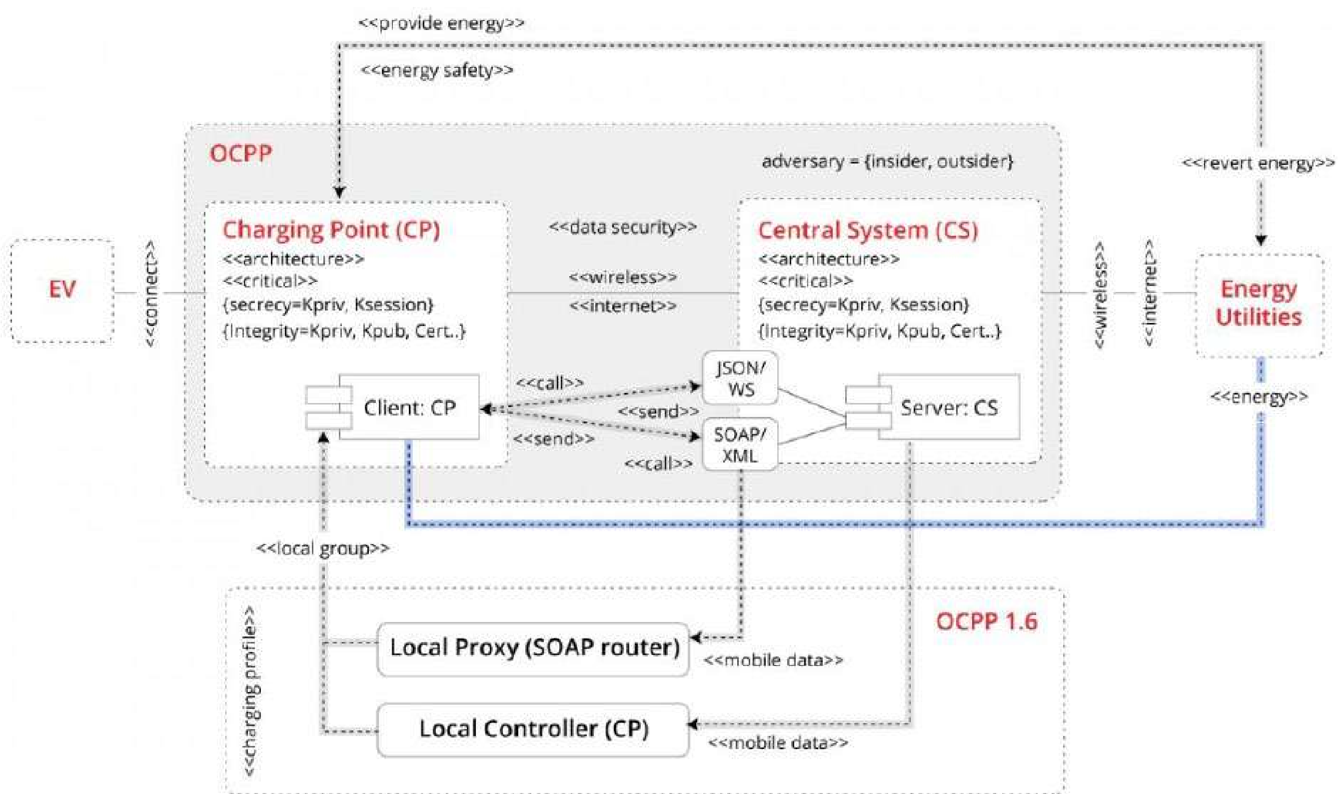
10.2.3 Open Charge Point Interface (OCPI)

OCPI is an independent roaming protocol that makes it easy to exchange data. The OCPI protocol is designed for exchanging information about charge points. The protocol is for exchanging information between the market roles of charge point operators and e-Mobility service provider. It can be used both by companies (peer-to-peer) and via a roaming hub or platform. With OCPI, EV drivers get an insight into the availability and costs of charging points. OCPI protocol is publicly available at no cost via Elad, Nederland.

10.2.4 Open Charge Point Protocol (OCPP)

OCPP is an application protocol for communication between EVSE and the software platform (or the central management system) to manage the EVSEs. A member-based association called Open Charge Alliance (OCA) in Netherlands has developed OCPP. It is based on open standards. All reputed EVSE manufacturers have integrated their EVSEs with OCPP version 1.5 and 1.6; so, do all the popular software platform providers. The OCPP has emerged as the industry's de-facto standard for communication between a charging station and a charging station management system, and is designed to accommodate any type of charging technique. It has been designed and developed to standardise the communications between an EV charge point and a central system used to operate and manage charge points. The communication protocol is open and freely available to switch from the charging network without necessarily replacing all the charging stations. OCPP 1.6 includes smart charging support for load balancing. The most recent version, OCPP 2.0, includes support for ISO/IEC 15118.

Figure 10-5: OCPP communication protocol



Source: ElaadNL

IEC is in the process of adopting OCPP. In the meantime, OCA has agreed to execute an MOU with BIS, India, so that BIS could adopt OCPP as an Indian Standard without any fee/royalties.

10.2.5 IEEE 2030.5 (IEEE Adoption of Smart Energy Profile 2.0 / SEP2)

The IEEE 2030.5 protocol is aimed primarily at in-house smart grid solutions called home energy management via internet-enabled devices (both wired and wireless). The protocol is based on the IEC 61968 for Common Information Model (CIM) and the IEC 61850 information model for DER. The protocol originates from the ZigBee Alliance and is a successor to the Zigbee smart energy protocol V1.

10.2.6 IEC 61850-90-8

The IEC 61850-90-8 describes an object model for electric mobility. It models EV as a specific form of DER according to the paradigms defined in IEC 61850. The main purpose of IEC 61850-90-8 is to model e-mobility into IEC61850-7-420, for the integration with other DER like PV, wind, etc. for a high level of safety and interoperability.

10.2.7 ISO/IEC 15118

ISO 15118 specifies the communication between EVs (including BEVs and PHEVs) and the EVSE. As the communication parts of this generic equipment are the Electric Vehicle Communication Controller (EVCC) and the Supply Equipment Communication Controller (SECC), ISO 15118 describes the communication between these components. The EV part of ISO 15118 specifies terms and definitions, general requirements and use cases as the basis for the other parts of ISO 15118. It provides a general overview and a common understanding of aspects influencing the charge process, payment and load leveling. ISO 15118 does not specify the vehicle internal communication between battery and charging equipment and the communication of the EVSE control centre or supply equipment control center (SECC) to other actors and equipment (beside some dedicated message elements related to the charging). ISO 15118 has been adopted by BIS and published as IS/ISO-15118. Following are the 6 parts already published:

IS/ISO 15118- 1: Vehicle to grid communication interface: Part 1 general information and Use-case definitions.

IS/ISO 15118- 2: Vehicle - To-Grid communication interface: Part 2 network and application protocol requirements.

IS/ISO 15118-3: Vehicle to grid communication interface: Part 3 physical and data link layer requirements.

IS/ISO 15118-4: Vehicle to grid communication interface: Part 4 network and application protocol conformance test.

IS/ISO 15118-5: Vehicle to grid communication interface: Part 5 physical layer and data link layer conformance test.

ISO/DIS 15118-6: Vehicle to grid communication interface: Part 6 general information and use-case definition for wireless communication (out of commission, merged with 2nd edition of ISO 15118-1)

ISO/CD 15118-7: Vehicle to grid communication interface: Part 7 network and application protocol requirements for wireless communication (out of commission, moved to ISO/DIS 15118-20).

IS/ISO 15118-8: Vehicle to grid communication interface: Part 8 physical layer and data link layer requirements for wireless communication.

ISO 15118-20: Vehicle to grid communication interface: Part 20 2nd generation network and application protocol requirements.

11 TECHNICAL REQUIREMENTS OF CHARGING STATIONS AND RECOMMENDATIONS

11.1 Specifications

EV charging infrastructure often referred to as EVSE, is a core component of a healthy EV ecosystem and requires adequate planning and dedicated electrical infrastructure (technical specifications) at various levels of the distribution grid. The overview of different charging methods, technical specifications and general requirements are currently used in India and globally mentioned below:

11.1.1 Slow AC Charging

Slow AC charging is the most basic form of charging in India and refers simply to plugging a car or two-wheeler into a standard three-pin 5A (type D) or 15A (type M) wall outlet without communication function to the on-board charger of the EV. These basic forms of charging are not enabled with managed charging capabilities and deliver about 5-15 km of range per hour, depending on plug and vehicle type.

11.1.1.1 Bharath EV AC Charger (AC 001)

Table 11-1: Bharath EV AC charger (AC 001) technical specifications and requirements

Sl No		Ratings
1	Specifications	• Maximum output power is 3.3 kW • Maximum output current is 15 A
2	Requirements	Input requirements: • AC supply system is 3 phase, 5 wire AC system (3 phases + N + PE) • Nominal input voltage is 415V (+6% and -10%) as per IS 12360 • Input frequency is 50Hz ± 1.5Hz Output requirements: • Number of outputs: 3 • Type of each output: A.C., 230V (+6% and -10%) single phase as per IS 12360 Environmental requirements: • Ambient temperature range: 0 to 55°C • Ambient humidity: 5 to 95% as per AIS 138 Part 1 • Ambient pressure: 86 kpa to 106 kpa as per AIS 138 Part 1 section 11.11.2.4 • Storage temperature: 0 to 60°C Communication requirements: • The EVSE should be able to communicate with CMS using Open Charge Point Protocol (OCPP) 2.0 • Metering: Grid responsive metering as per unit consumption of the vehicle. Both the AC and DC outputs shall be metered separately

Source: BESCOM

11.1.2 Moderate AC Charging

Moderate AC charging requires installing a dedicated EV charger to a 15A single phase circuit with managed charging capabilities. Charging rates start at 2.5 kW and can go up to 20 kW depending on the type of EVSE installed and the model of the car connected. Indian cars are currently limited to 3 kW, and most global OEM vehicles are limited at 7.7 kW.

11.1.3 DC Fast Charging

DC fast charging is typically used when the vehicle requires a rapid charge and the user/owner is willing to pay a premium for the faster charge. DC fast-charging stations are almost always commercial operations owned and/or operated by a charge network operator. It requires dedicated grid infrastructure and some level of Discom engagement in the planning and design phase. It is rarely used as the primary mode of private vehicle charging and rarely used as a dedicated charger for an individual car. Stations are often deployed in public areas and are owned and operated by a charging network operator that provides charging services to EV owners at a set cost. Heavy-duty and medium-duty vehicles and buses typically require some form of DC fast charging to achieve a reasonable recharge time for their larger batteries.

11.1.3.1 Bharath EV DC Charger (DC 001)

Table 11-2: Bharath EV DC charger (DC 001) technical specifications and requirements

Sl No		Ratings
Level 1 DC Charger		
1	Specifications	• Public DC chargers with output voltage of upto 100V • Power outputs of 15 kW • Maximum current of up to 200A
2	Requirements	Input requirements: • AC supply system is 3 phase, 5 wire AC system (3 phases + N + PE) • Nominal input voltage is 415V (+6% and -10%) as per IS 12360 • Input frequency is 50Hz ± 1.5Hz Output requirements: • Number of outputs: 2 • Output 1: To be used for 10 kW or 15 kW charging, connector is GB/T20234.3 • Output 2: connector to be used for 3.3 kW AC charging shall be industrial socket of 16A rating complying with IEC60309 Environmental requirements: • Ambient temperature range: 0 to 55°C • Ambient humidity: 5 to 95% as per AIS 138 Part 1 • Ambient pressure: 86 kpa to 106 kpa as per AIS 138 Part 1 section 11.11.2.4 • Storage temperature: 0 to 60°C Communication requirements: • Dedicated CAN communication is used for digital communication between a DC EV charging station and an EV for control of DC charging
Level 2 DC Charger		
1	Specifications	• Public DC chargers with output voltage of upto 1000 V • Power outputs of 30 kW–150 kW
2	Requirements	Input requirements: • A.C. supply system is 3 phase, 5 wire AC system (3 phases + N + PE) • Nominal input voltage is 415 V (+6% and -10%) as per IS 12360 • Input frequency is 50Hz ± 1.5 Hz Output requirements: • Number of outputs: 2 (1 x CCS type 2 & 1 x CHAdeMO) • Charging mode: Mode 4 – DC Charging as per the IEC 61851 standards Environmental requirements: • Ambient temperature range: 0 to 55°C • Ambient humidity: 5 to 95% as per AIS 138 Part 1 • Ambient pressure: 86 kpa to 106 kpa as per AIS 138 Part 1 section 11.11.2.4 • Storage temperature: 0 to 60°C Communication requirements: • The conductive digital communication between DC EVSE and EV shall comply with the IEC-61851-24: 2014

Source: BESCOM

11.2 Charger Operations (Technical)

Public charging infrastructure should meet the following minimum technical requirements as per the MoP guidelines issued on 01 October 2020:

- All stations must have an exclusive transformer with all related substation equipment, including safety appliance
- All stations must have 33/11 kV lines/cables with associated equipment, including as needed for line termination/metering
- Appropriate civil works
- Current international standards that are prevalent and used by most vehicle manufactures internationally are CCS and CHAdeMO. Hence, public charging stations must have one or more electric kiosks/ boards with the installation of all the charger models, as shown in Table 11-3

Table 11-3: Public charging infrastructure requirements

Charger Type	Sl No	Charger Connectors	Rated Output Voltage (V)	No. of connector guns	Charging Vehicle Type
Fast	1	CCS (min 50kW)	200-750 or higher	1CG	4W
	2	CHAdeMO (min 50 kW)	200-500 or higher	1CG	4W
	3	Type-2 AC (min 22 kW)	380-415	1CG	4W, 3W and 2W
Slow/Moderate	4	Bharat DC-001 (15 kW)	48	1CG	4W, 3W and 2W
	5	Bharat DC-001 (15 kW)	72 or higher	1CG	4W
	6	Bharat AC-001 (10 kW)	230	3CG of 3.3 kW each	4W, 3W and 2W

Source: MoP

Table 11-4: Charging power and energy requirements of different segments

Vehicle Type	Battery Size	Slow Charging	Fast Charging
2-W	1-3 kWh	0.5-1 kW	2-3 kW
3-W	3-7 kWh	0.5-1 kW	2-3 kW
4-W	15-80 kWh	3 kW	20-100 kW
Buses	100-400 kWh	7-50 kW	50-500 kW

- The public charging station provider is free to create charging hubs and to install additional chargers in addition to the minimum number of chargers given above
- The charging provider must tie-up with at least one online network service provider (NSP) to enable advance remote/online booking of charging slots by EV owners. Such online information to EV owners should also include information regarding location, types, and numbers

- Charging station operators must share charging station data with the appropriate Discom and maintain appropriate protocols as given by such Discoms for this purpose. CEA and MoP shall have access to this database.

11.3 Charger Maintenance

Public EV chargers require some level of service and maintenance like any other device available for public usage and exposed to the environment. The service of public chargers is taken care of by the charger owner/operator. Therefore, it is not a relevant consideration for DISCOMs not providing the charging infrastructure, however DISCOMs that choose to own public charging stations should also plan regular service and maintenance of those assets.

11.4 Skills and Training for Operators and Maintenance Personnel at Charging Stations

11.4.1 Building a Utility Transportation Electrification Team

Those that operate cross-functionally to combine the capabilities of internal departments to assist with customer engagement are the most effective utility EV programme initiatives. As a programme is constructed, initiated and introduced, a transport electrification team will promote internal coordination and leadership. A list of utility departments and how they can support EV charging infrastructure programs is featured in the Table below. Regardless of the size of the team, these divisions will serve as a team extension to more widely spread the messaging of the EV charging programme into their business practices. This would help to improve customer loyalty. In addition, meeting with these departments early in creating the programme would help decide and prioritize the transport electrification team's organizational resources.

While the gold standard for utilities in terms of enhancing EV infrastructure planning and implementation processes is dedicated to the cross-functional transportation electrification team. The resources needed to deal with EV charging infrastructure might not be justified by smaller utilities with restricted EV deployment in their service territories. Therefore, it is important to understand the functionality of a utility's departments and how they can be leveraged to grow the program's reach without increasing staff in the short term.

Before creating a dedicated transportation electrification team, utilities can support EV and charging infrastructure growth by:

- Designating a lead point of contact for EV infrastructure customers
- Establishing a full-time EV program manager position that guides EV infrastructure program activities across all departments
- Hiring a contractor to manage EV program activities, such as tracking customer progress from sign-up to installation or performing site walks
- Establishing a separate interconnection queue for charging infrastructure projects. So these projects can be prioritized appropriately

There are several ways to organize the team when a utility is ready to form a dedicated transportation electrification team.

Table 11-5: Utility departments involved in EV charging programs

Department	Responsibilities
EV Project Management Team	Guides and facilitates internal and external roll out of EV programs and activities.
Executive Management and Team	Regularly emphasizes the importance of the utility's transportation electrification efforts to employees in departments across the utility. Should be continually updated on EV strategic plans and program progress.
Rate Design	Studies, develops, and implements new rate designs tailored for EV charging. Works closely with the transportation electrification team and the regulatory team to determine rate use cases and impacts.
Public Affairs	Ensures governmental and other key stakeholders (e.g., mayors and their staff) understand the benefits to residents and businesses.
Media Relations	Coordinates outreach to local media with details about EV programs and milestones. Coordinates social media and blog posts.
Customer Contact Center	Ensures staff is trained to respond effectively to customer queries via phone, social media, and online chat regarding EV programs, home charging, rates and incentives, and other relevant information.
Construction	Coordinates with contractors to install EV charging infrastructure and other related activities.
Technology and Innovation	Approves charging equipment offered by the program to ensure safety, reliability and evaluates energy management systems, technical standards, communications protocols and interoperability, energy storage integration, vehicle-to-grid and other advanced technology systems.
Strategy	Helps to develop the programs and activities undertaken by the utility via an EV strategic plan. Also oversees the development of new utility business plans.
Regulatory	Secures regulatory approval for new EV program designs and funding and ensures public policy decision-makers are updated on EV program and activity progress, customer participation, and public benefits associated with transportation electrification.
Customer Research and Communications	Provides customer segmentation data to target the marketing strategy and implements the marketing strategy to increase customer program enrollment, EV purchases, and other community outreach and information.
Community Relations	Leads outreach efforts to community-based organizations to work with leaders representing low-income and underserved communities.
Commercial Account Managers	Provides program information to large corporate customer accounts. This is often one of the most important groups to reach out to site hosts because customers typically trust the group.
Fleet	Develop and implement a strategy to convert a portion of the utility fleet to EVs to ensure the utility is "walking the talk." Can be showcased as testimonials for customers interested in fleet electrification. Utility workplace charging could also be included as part of a comprehensive approach to utility fleet electrification.
Engineering & Planning	Assesses the need for utility service upgrades and determines the infrastructure design and installation requirements.
Grid Operations	Monitor and manage the utility's transmission and/or distribution grid, including aggregated DER programs, such as managed charging.

11.4.2 Potential Staffing Approaches for Transportation Electrification Team

To effectively manage EV infrastructure programmes, there are several different ways to create utility teams. Utilities also have dedicated teams consisting of two to 10 members for transport electrification. Regardless of size, the significance of a committed team is that utility employees are accountable and responsible for EV infrastructure operations. In addition, a best practice for the utility EV team can leverage key internal departments that can help make the EV program successful. Below are examples of different potential utility staffing approaches.

11.4.2.1 Smaller Team: Two Team Members

- **EV Team Manager/Director:** EV charging infrastructure specialist who works with management to direct the EV approach. To learn best practices, attend activities and engage in trade associations, and lead regulatory efforts

- **Education and Outreach Manager:** Leads the education and outreach portion of the EV strategy. Works cross-functionally to provide key departments with the needed materials for their stakeholder and customer outreach efforts. Oversees implementation of the marketing plan, which could include customer journey mapping, EV test drives, dealership outreach, internal employee education, and website development

11.4.2.2 Medium-Size Team: Five Team Members

Same two team members as above, plus a growing focus on team members who can develop EV charging infrastructure programs that will gain regulatory approval.

- **EV charging and infrastructure expert:** Focuses on developing efficient EV charging utility and regulatory filings infrastructure systems. Creates RFIs, RFQs and RFPs and works to understand the available technologies with charging vendors.

- **Regulatory Manager:** Focuses on drafting EVSE program design elements for regulatory filings.

- **Education and Outreach Support Manager:** Supports the education and outreach manager to execute the marketing campaign and the management of EV test drives, distributor outreach and educational activities for internal employees.

11.4.2.3 Larger Team: Ten or More Team Members

Same five team members as above, plus a growing focus on developing sales and operations team for EV charging program implementation.

- **Program Manager:** Develops the promotional plan for a programme for EV charging. Supervises team managers, sales and cross-functional coordination with other departments to ensure clear programme communications and the achievement of departmental sales objectives.

- **Sales:** The activity of sales team members is not common for utilities that are new to EV charging systems. However, the role is similar to a sales role when implementing such programmes, and the aim is to help achieve the key success metrics of the programme.

- **Construction Project Manager:** Works with procurement, operations and construction departments to manage charging inventory and creates customer EV charging infrastructure construction schedules.

- **MD/HD Charging Infrastructure Expert:** Focuses on improving infrastructure systems for medium and heavy-duty charging. Works with charging suppliers to recognize the technologies available and works with the regulatory manager to develop new filings for the programme.

- **Financial/Regulatory Analyst:** Focus on regulatory disclosures and financial programmes, including review of sales and business models and environmental impacts.

11.5 Recommendations

Electric utilities have a significant role to play in improving the integration of EVs with the grid. First, utilities support EV charging infrastructure deployment through direct procurement, providing rebates or other incentives to encourage customer and third-party investments, and by requiring open protocols as a component of a utility managed program. Second, utilities contribute to the development of the standards for managed charging equipment. Third, they support the evolution of software and other methods used to modulate charging rates or shift charging events to provide grid services. BESCOM has an important role in the outcome of these variables by:

- Providing thought leadership on charging use-cases, including needs, applications, proper valuation, testing, and validation
- Participating in the charging communication standards development process
- Collaborating with industry to adopt standards and best practices
- Providing a testbed or pilot effort for new solutions
- Developing solutions to integrate EV charging into demand response systems
- Providing EV education and awareness to their consumers

Key takeaways for utilities aiming to improve EV charging infrastructure processes include:

- Develop a holistic EV strategic plan that accurately recognizes the dynamics of the EV market
- Create a transportation electrification team that operates cross-functionally, preferably to exploit other internal departments' abilities to enhance programme effectiveness and customer interaction
- Incorporate best practices defined for EV charging infrastructure initiatives led by the utility. The areas of planning, customer engagement, appraisal, design and development and customer and regulatory follow-up are covered by these best practices.
- Incorporate best practices identified for third-party EV charging infrastructure projects. These best practices address the areas of internal planning, customer engagement, and design and construction.
- Consider services and process enhancements that can use EVs to help low-income and unreserved consumers and encourage transit and health equity

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