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India Smart Grid Forum

DISTRIBUTION UTILITY MEET DUM 2023

Session-2 : GROWTH OF RE AND EV; AND THE PLAN FOR ENHANCING GRID FLEXIBILITY

Vehicle-to-Grid: Technology and Grid support services

GRID INTEGRATION LABORATORY
IIT BOMBAY

Presented By

Prof. Zakir Rather, IIT Bombay (zakir.rather@iitb.ac.in)



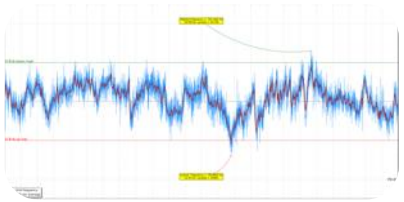


EV batteries –multiple applications = Like a Swiss Army knife

Driving

Vehicle to Home

Community emergency power



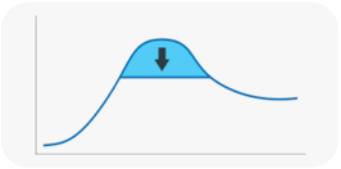
Frequency Regulation

Peak/off-peak arbitration

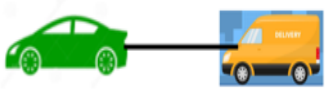
Rivian R1T lit Christmas tree

Tesla Cybertruck charges CyberQuad ATV

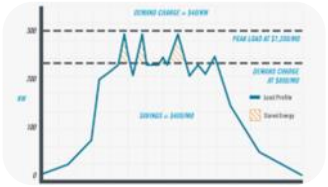
EV Battery



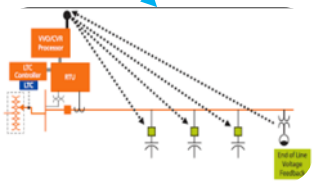
Demand Response



Vehicle-to-Vehicle



Demand side Management



Voltage Management

Vehicle-to-Load

Many projects form a solid foundation for better understanding and scaling V2G

V2G evolution is accelerating

"BIRTH"

Demo PROJECTS

COMMERCIAL DEPLOYMENTS

FAST SCALING GW/GWh

V2G
The idea is borne

26 BMW e-Mini/UDEL 2013-2015

Nikola
2 Nissan Leaf
2013-2016

NIKOLA
INTELLIGENT ELECTRIC VEHICLE INTEGRATION

Parker
10 Nissan e-nv200
2016-2019

INVENT
30+ V1G/V2G
2017-2020

UNDP Namibia
2 Nissan Leaf
2019-2020

FREDERIKSBERG FORSYNING
2016-2023

- **Price parity ICE/EV**
- **V2G Regulation/Innovation**
- **V2G Standards/Interoperability**
- **Technology (1-Million-mile battery)**
- **V2X Supply chain acceleration**

1996/1997 **2013 - 2020** **2022** **2030**

The EV models in the market are growing fast

Both unidirectional and bidirectional EVs

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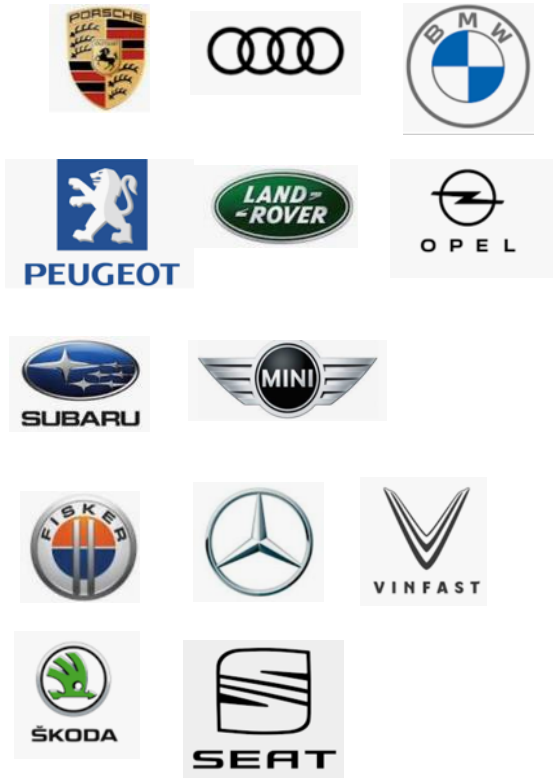
Unidirectional EVs



+ Many Chinese EVs

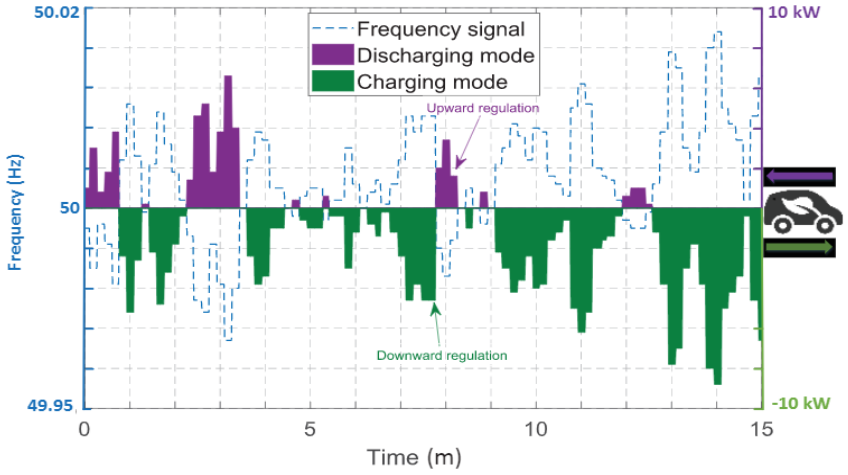
Bidirectional V2X EVs

4

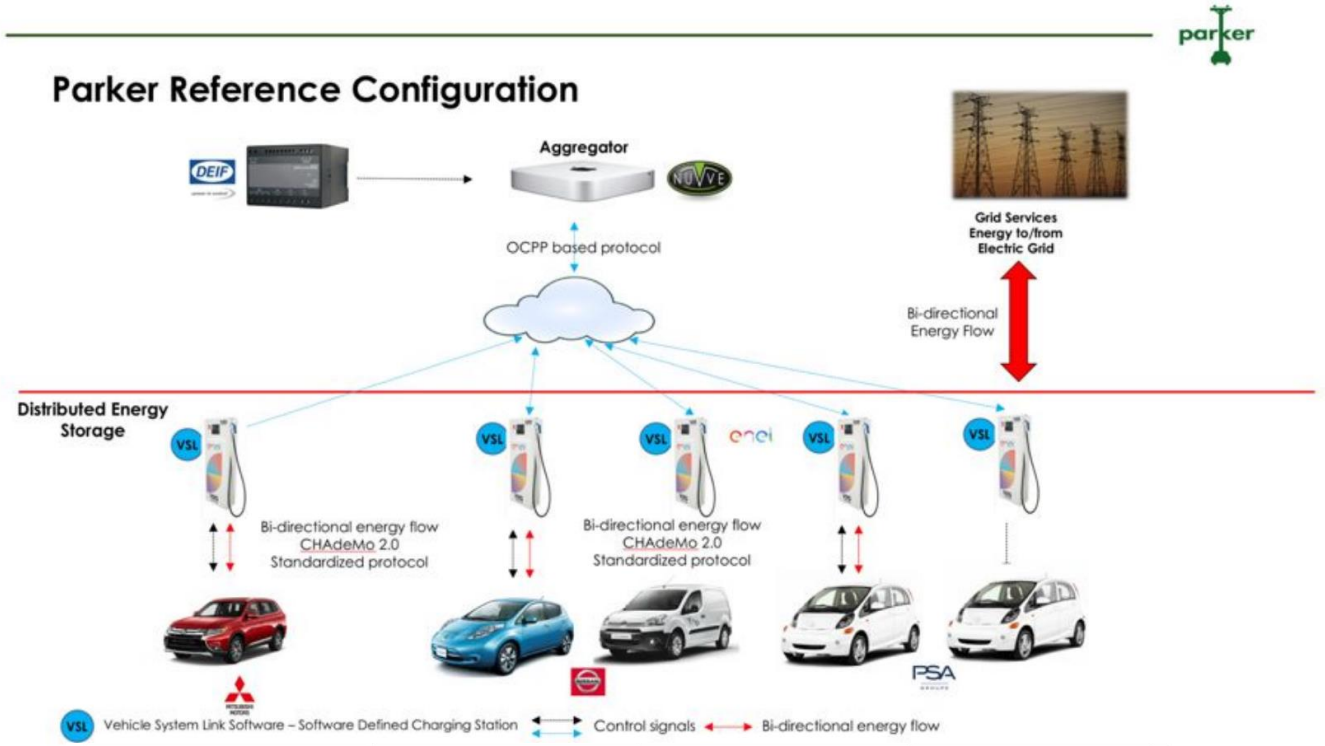
Parker project

(August 2016 to July 2018)

Vehicles		
Parker Vehicle ID	**Vehicle Brand/Model**	**Battery size (kWh)**
DTU Leaf	Nissan Leaf	30
DTU Evalia	Nissan Evalia	24
DTU Outlander	Mitsubishi Outlander	12
DTU iOn	PSA iOn	16
DTU iOn2	PSA iOn	16
EVSEs	**Enel V2G Chargers**	**+-10kW**
Freq. Measurement	**DEIF MTR-3**	
Aggregator	**Nuvve GIVe**	**Cloud based**



Regulation service provided by an EV



DK2

Period	FCR-N DK2 Price/MWh-h	Weekly Revenue/car@9.25 kW	Projected Yearly Revenue per car
Feb 06-13, 2017	€12.80	€13.97	€726.50
May 22-29, 2017	€17.91	€19.55	€1,016.54
Aug 07-14, 2017	€19.54	€21.33	€1,109.05
Nov 06-13, 2017	€13.46	€14.69	€763.96
Jan 01 - Dec 31, 2017	€27.88		€1,710.72
Jan 01 - Oct 11, 2018	€40.52		€2,486.31

FRRS Pilot, United States of America

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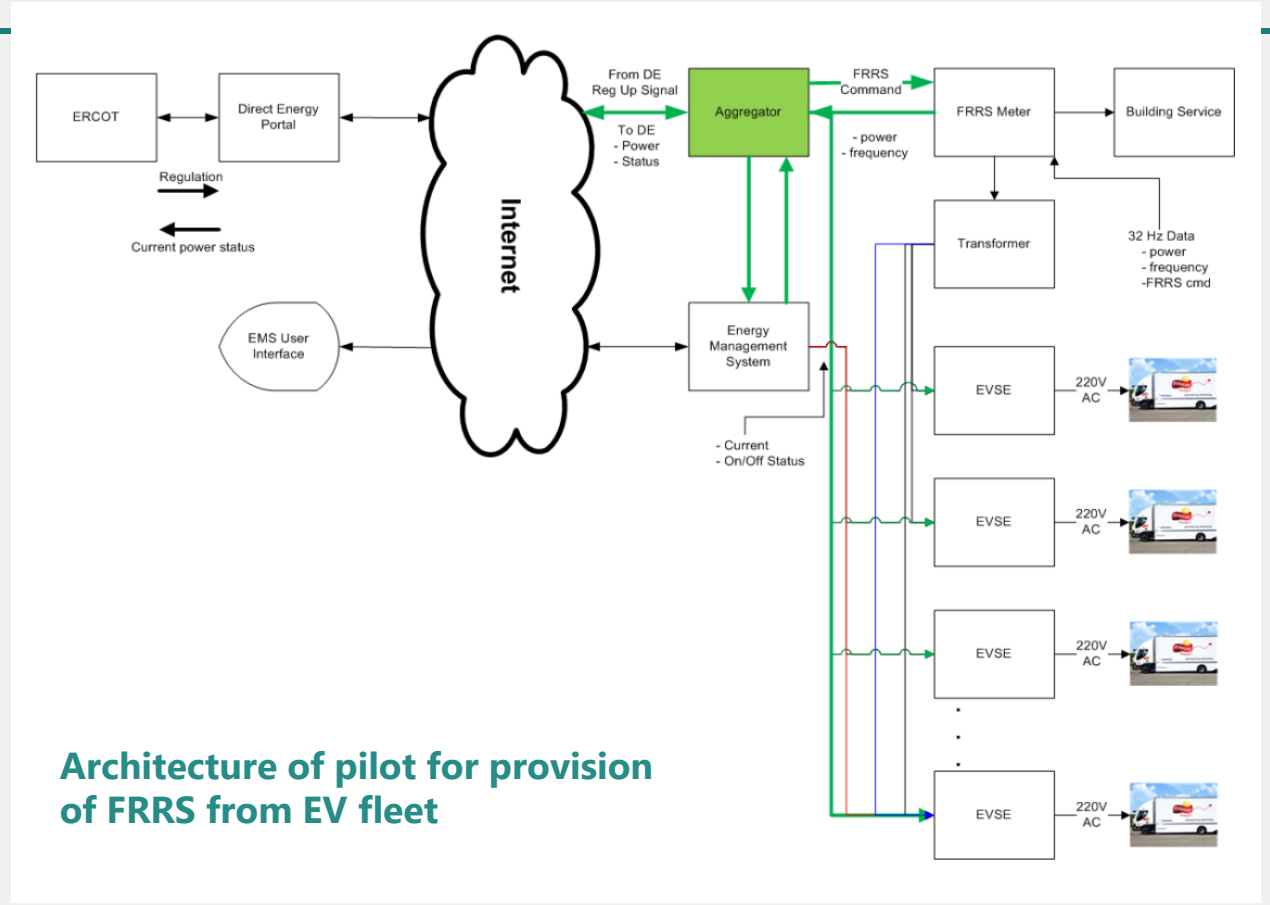
Frequency regulation service using EV fleet, pilot case study by ERCOT (2013-2015)

- A fleet of 11 EVs were used
- An EV aggregation control system was developed that would control the EV charging based on either control signal from ERCOT or local frequency deviations.
- The operator is required to pay a fee per month to the Qualified Scheduling Entity (QSE) service for maintaining the communication link between ERCOT and the fleet aggregator.



Architecture of pilot for provision of FRRS from EV fleet

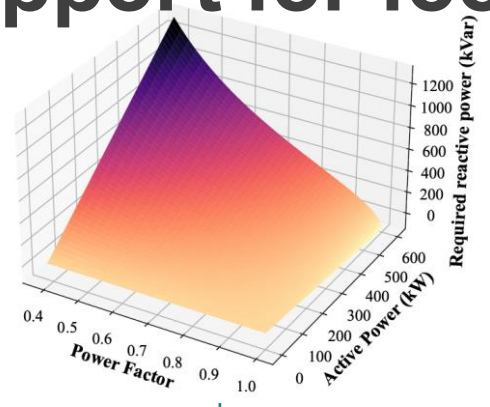
Hour ending	Price per 100 kWh (INR/ EUR)	30 days income (INR/EUR)
6:00 pm	114.9/ 1.304	3449.92/ 39.168
7:00 pm	252.09/ 2.862	7560.47/ 85.836
9:00 pm	191.29/ 2.172	5729.11/ 65.04
9:00 pm	105.28/ 1.195	3144.45/ 35.69
	Total	19892.12/ 225.841

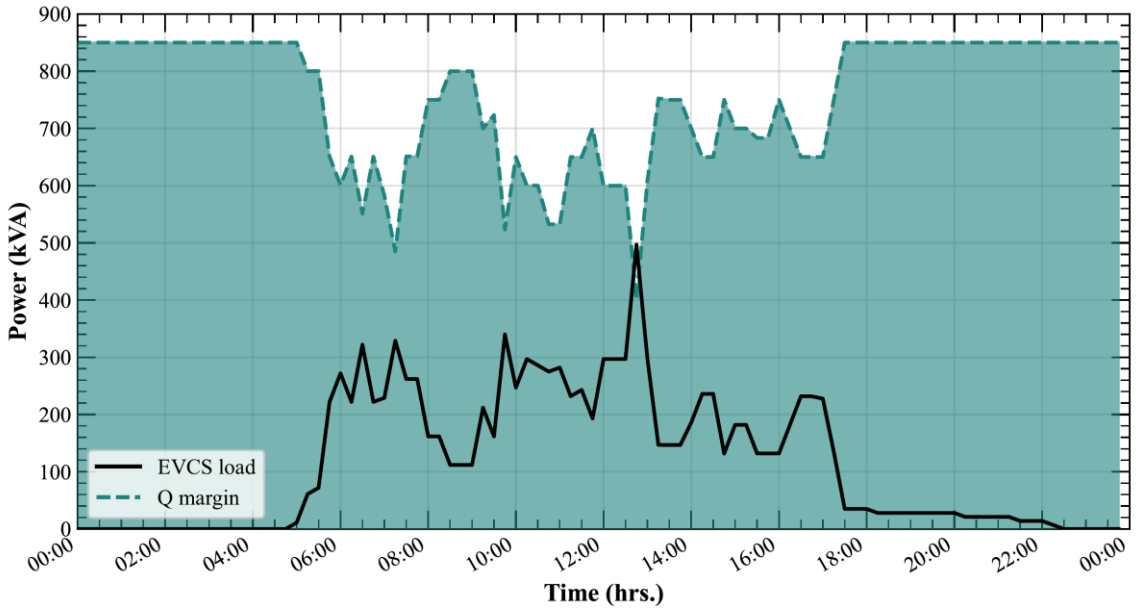
Total EV fleet potential revenue for participating in the 5:00pm-9:00 pm timeframe

Technology Solutions for Wind Integration in ERCOT. In U. S. Department of Energy (DE-OE0000194). Commercialization of Electric Techno

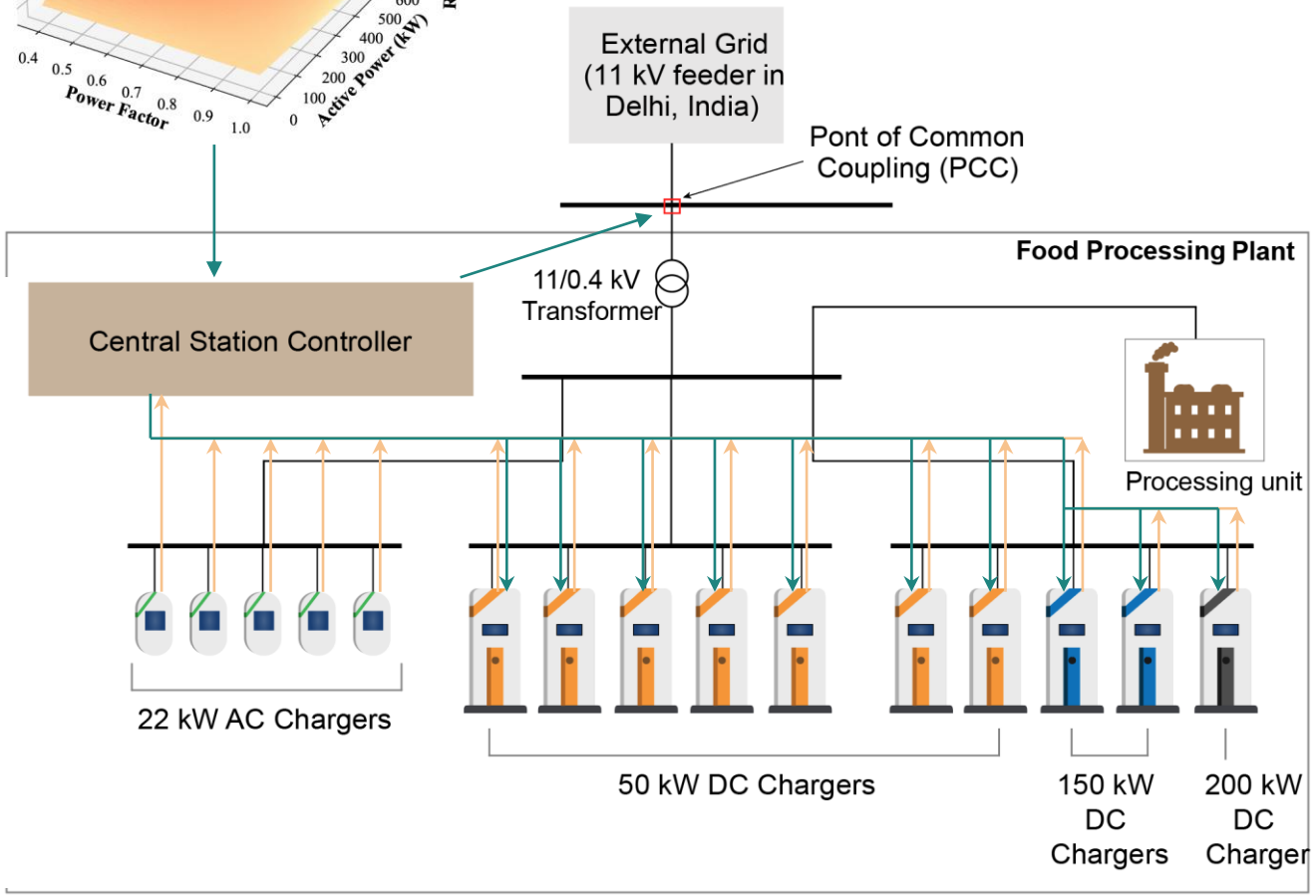
Use case-Reactive power support for food processing Industry in Delhi

A ***central station controller (CSC)*** has been used in this study to regulate the ***PF at the PCC above 0.98***.





Controller Design

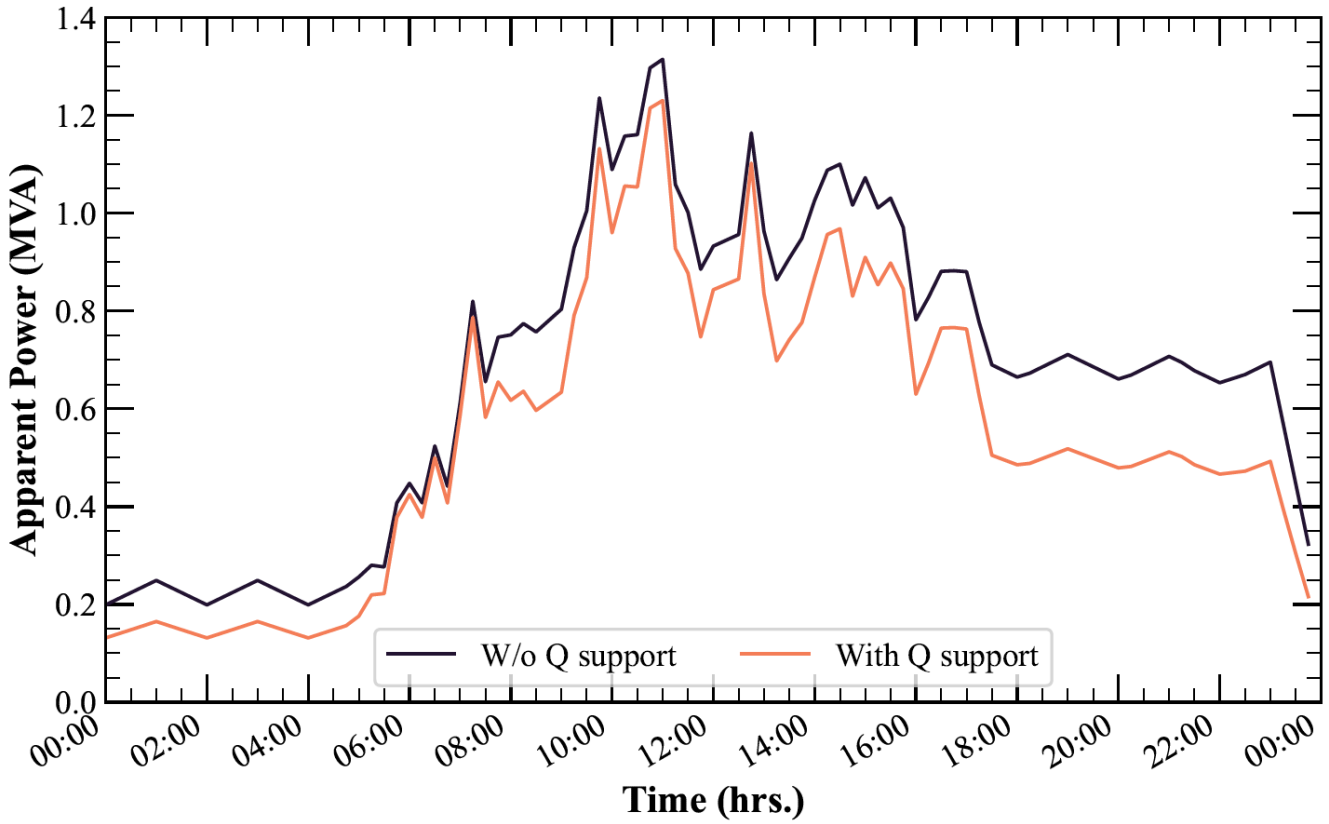


Overview of the system

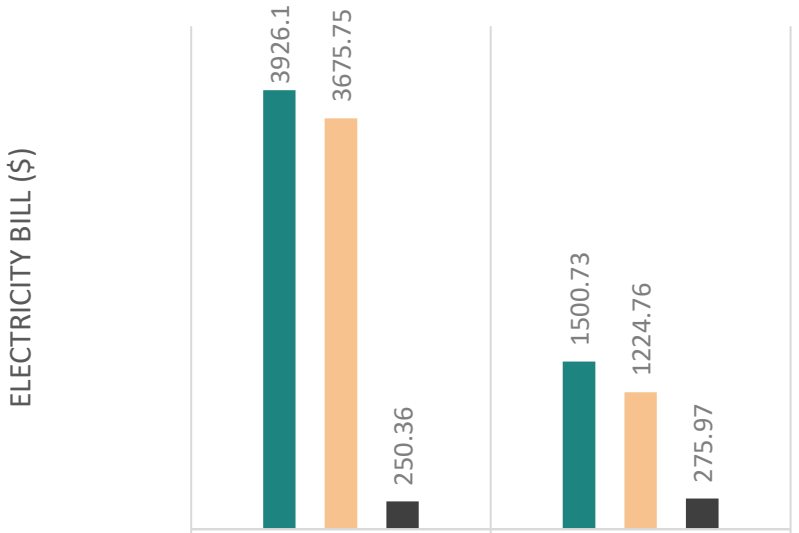
Reduction in Apparent power drawn and total savings due to Q support from EVCS

- With the reactive power injection from the EVCS, the reactive power drawn from the grid reduced.
- This led to reduction in apparent power consumed by the industry and also the MD.

Apparent Power with and without Q support from EVCS



Electricity bill for the industry



	Demand Charge ($/Month)	Energy Charge ($/Day)
Without Q	3926.1	1500.73
With Q	3675.75	1224.76
Savings	250.36	275.97

Annual Savings ($) 3004.32 86,382.84

Total Annual Savings **$89,387**

Use case- Frequency Regulation Service in Indian Grid

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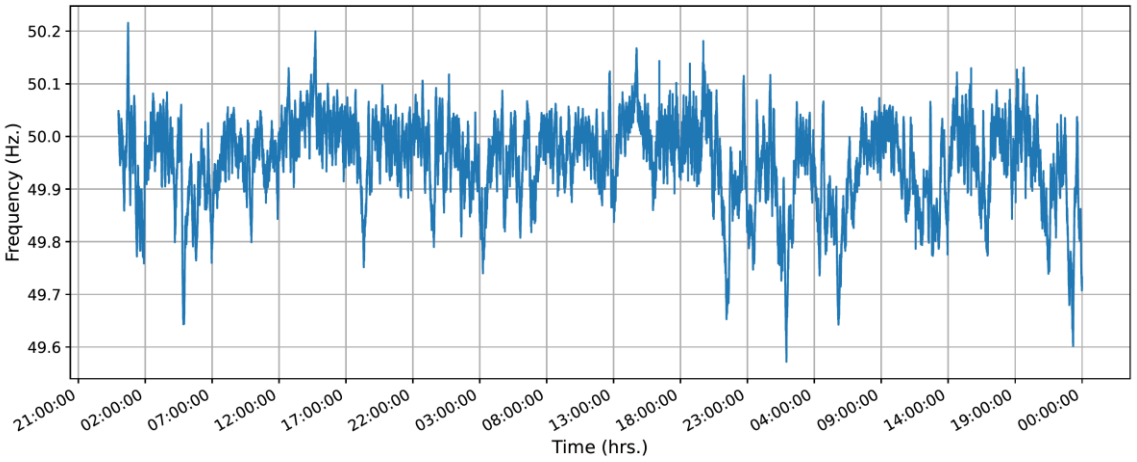
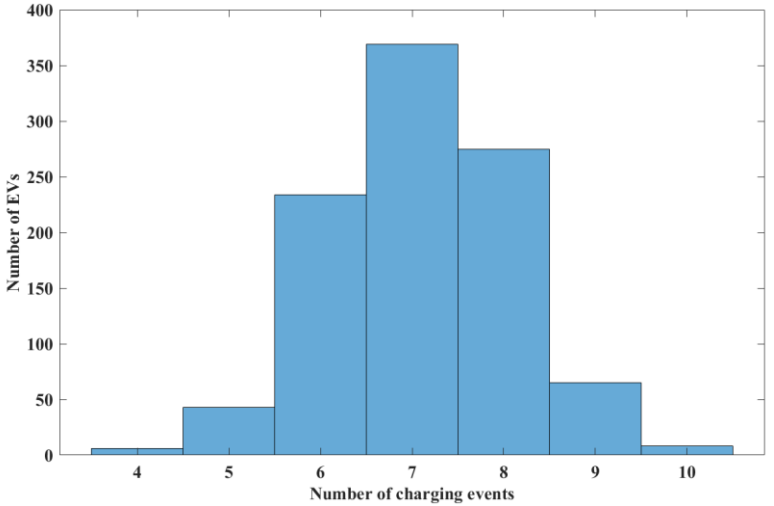
Frequency data (measured at IITB Campus)



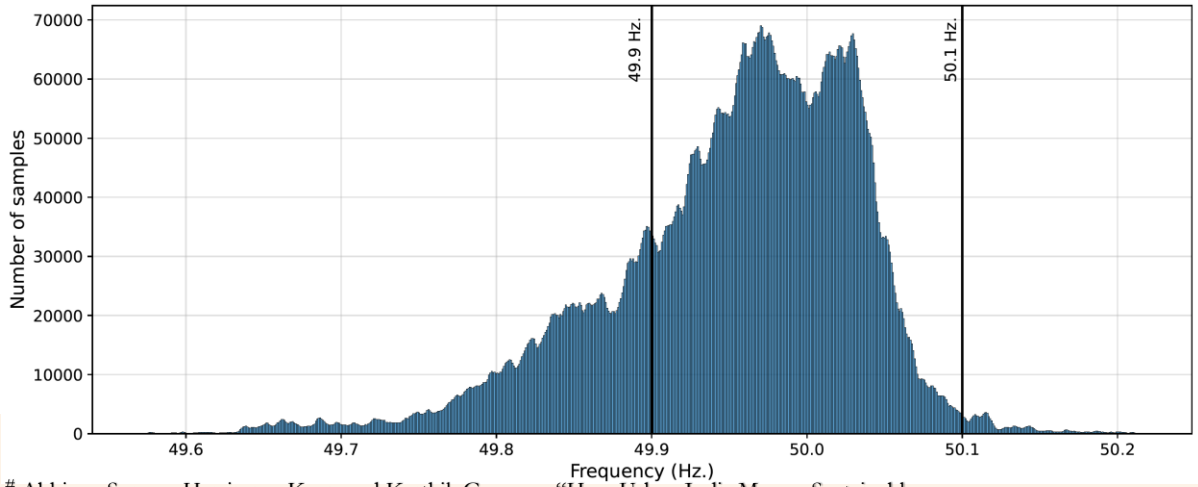
Details of EV considered

Electrical Vehicle Parameters	Value
Size of EV Battery (kWh)	40
Charger Rating (kW)	22
Minimum SoC	0.2
Maximum SoC	0.9
Charger Efficiency (%)	90
EV consumption (kWh/km)	0.15
EV aggregator size	1000

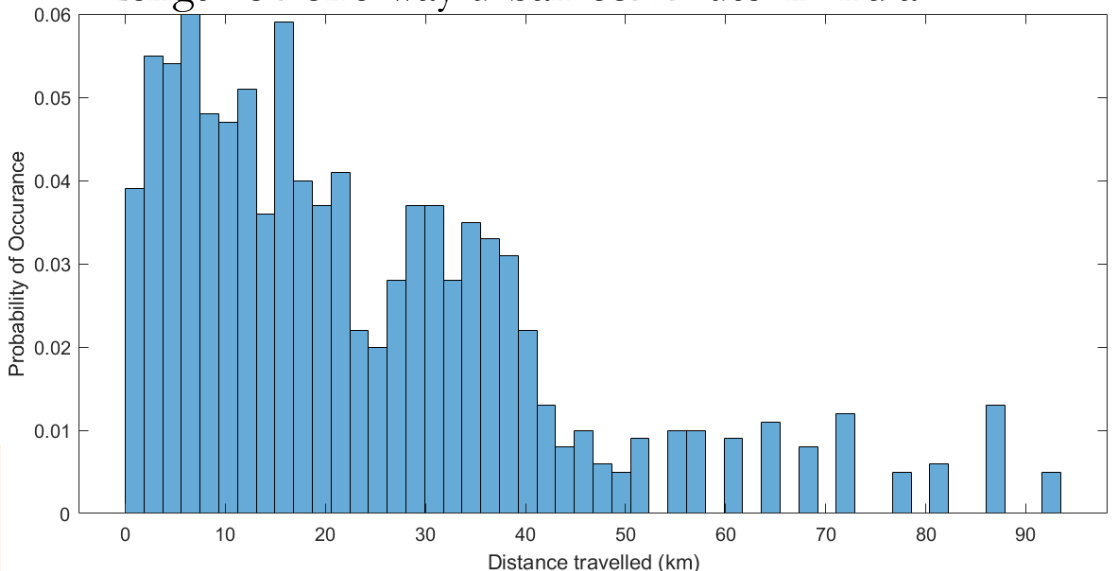
Histogram showing the number of charging events in 30 days



Histogram plot of the frequency measurement data

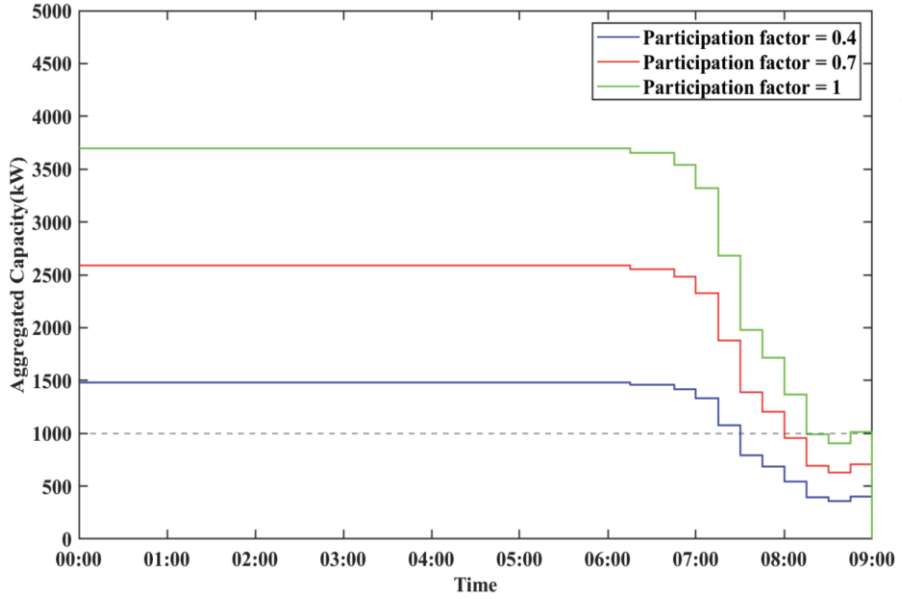


Length of one-way urban commute in India#



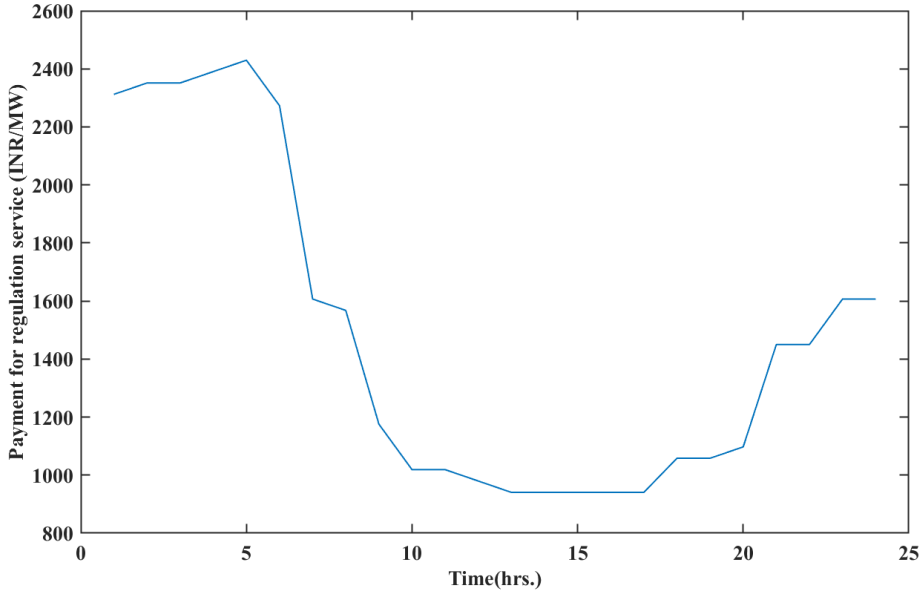
Abhinav Soman, Harsimran Kaur, and Karthik Ganesan, "How Urban India Moves: Sustainable Mobility and Citizen Preferences," October 2019

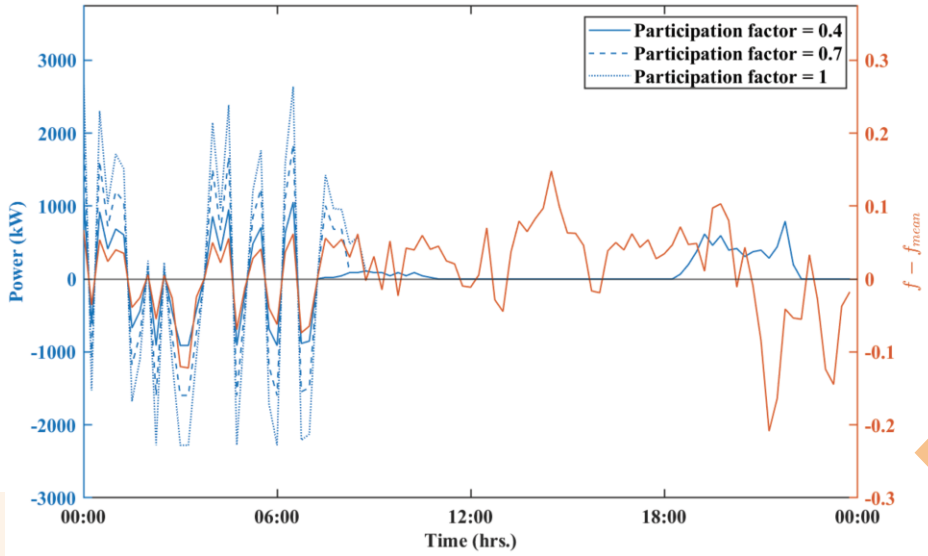
Frequency Regulation Response



Regulation reserve available with the aggregator for different time slots (shown for 1 day)

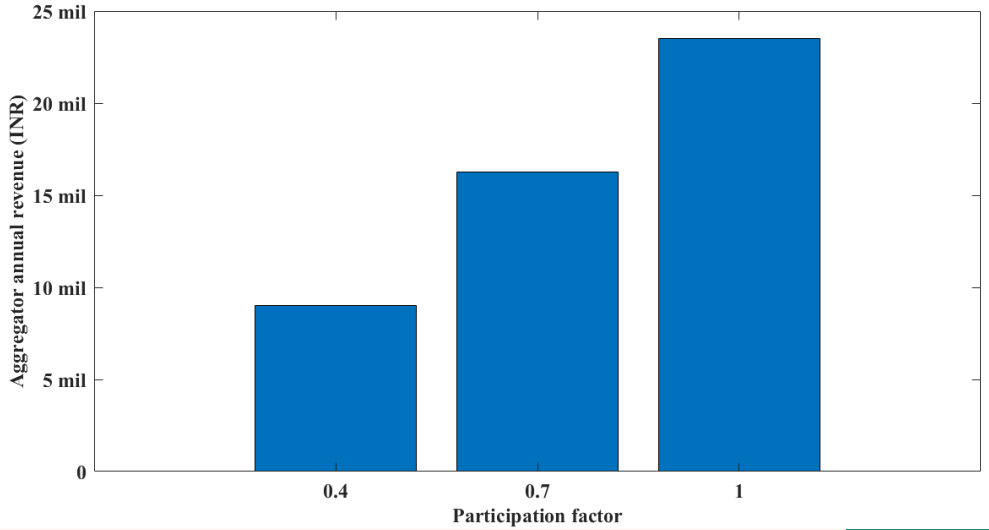
Payment for regulation service#





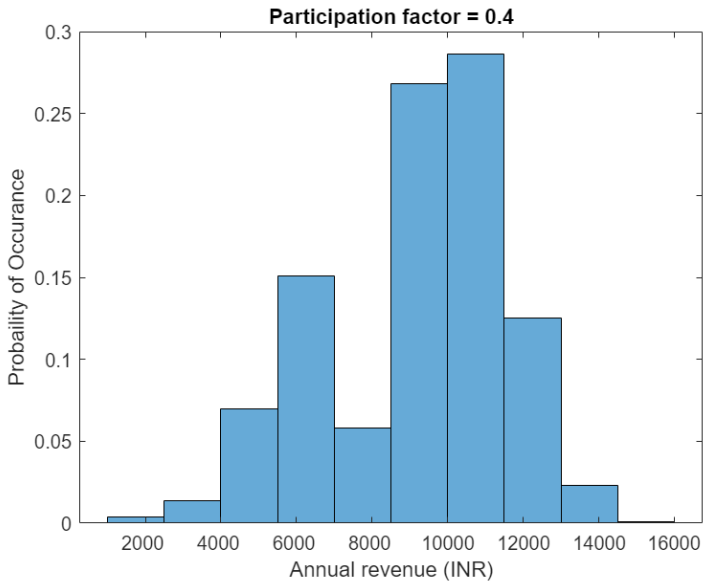
Frequency regulation service provided by the EV aggregator (shown for 1 day)

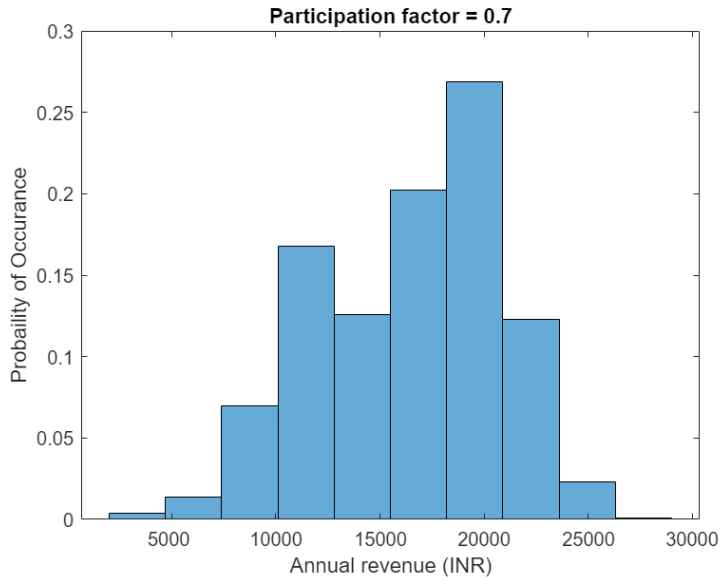
Aggregator annual revenue by the provision of frequency regulation service

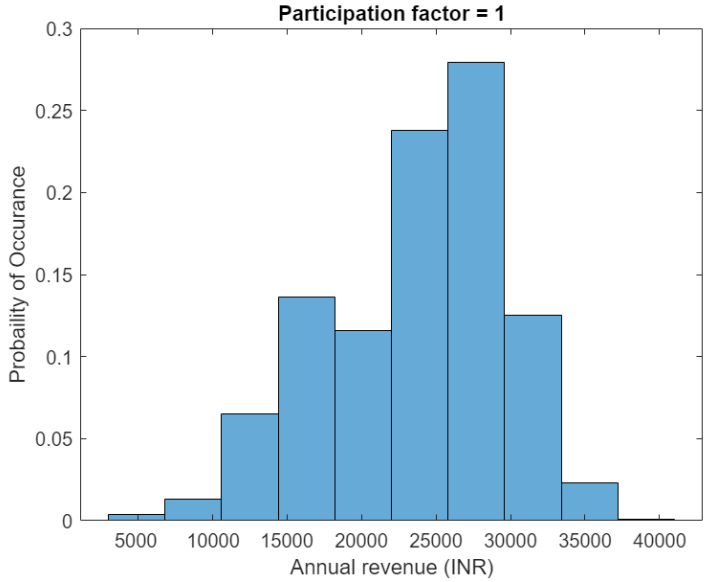


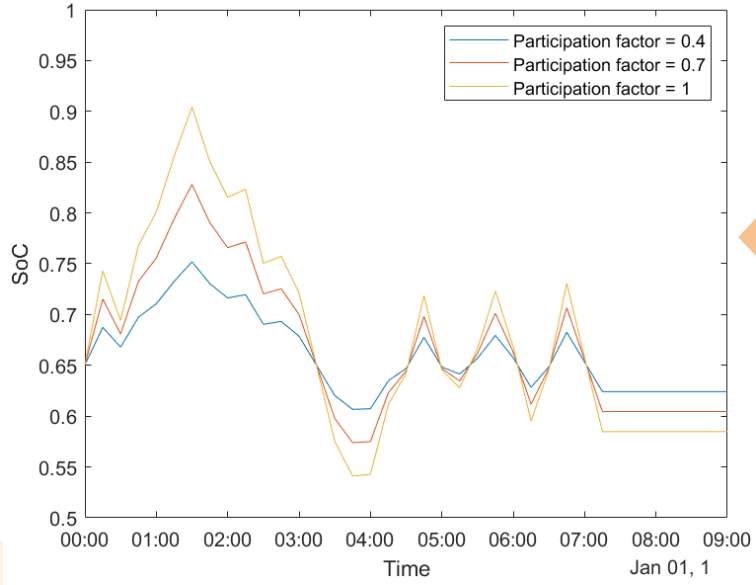
The price has been mapped from the Danish frequency regulation price

Annual Revenue earned by each EV user









State of Charge of EV due to the provision of regulation service.

If the EV user wants higher profit for participating in regulation service, they would be subjected to higher SoC swings, which may hamper the travel requirements of the user.

Need for EV Regulations in India

- **Regulations on EV Charging**
  - **Regulations by CEA**
    - Amendment to Technical Standards for connectivity of DG resources, issuing guidelines for connectivity of EV charging station below 33 kV voltage level – **February 2019**
    - Amendment to Measures relating to Safety and Electric Supply – **June 2019**
  - **MoP Charging Infrastructure Guidelines**
    - First Guidelines – **December 2018**
    - 1st revision – **October 2019**
    - 2nd revision – **January 2022**

Minimum control functionality requirements for EVs, Denmark

	A1	A2	B	C	D
Frequency Response (Over frequency)	✓	✓	✓	✓	✓
Frequency response (Under frequency)	-	-	-	✓	✓
Frequency control	-	-	-	✓	✓
Absolute power limit	✓	✓	✓	✓	✓
Ramp rate limit	✓	✓	✓	✓	✓
Q Control	✓	✓	✓	✓	✓
Power Factor Control	✓	✓	✓	✓	✓
Automatic Power Factor Control	✓	✓	-	-	-
Voltage Control	-	-	-	✓	✓

Category of Charging Stations

Category	Rated Power
A1	$x \leq 11\ kW$
A2	$11\ kW < x \leq 50\ kW$
B	$50\ kW < x \leq 1.5\ MW$
C	$1.5\ MW < x \leq 25\ MW$
D	$25\ MW < x$

V2G Demonstration Pilot-1 at IIT Bombay

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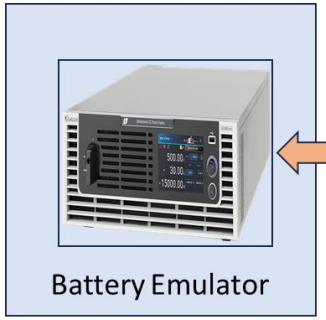
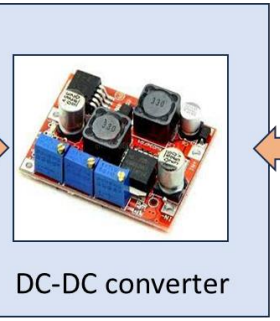
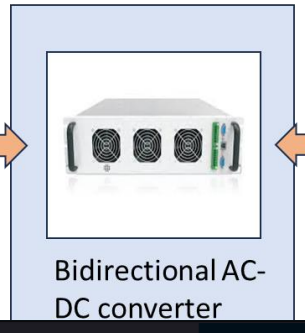
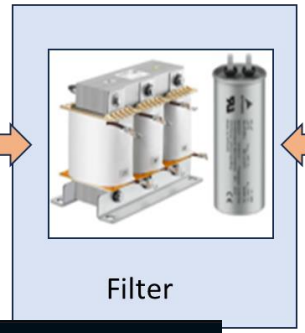
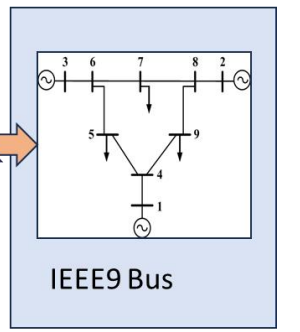
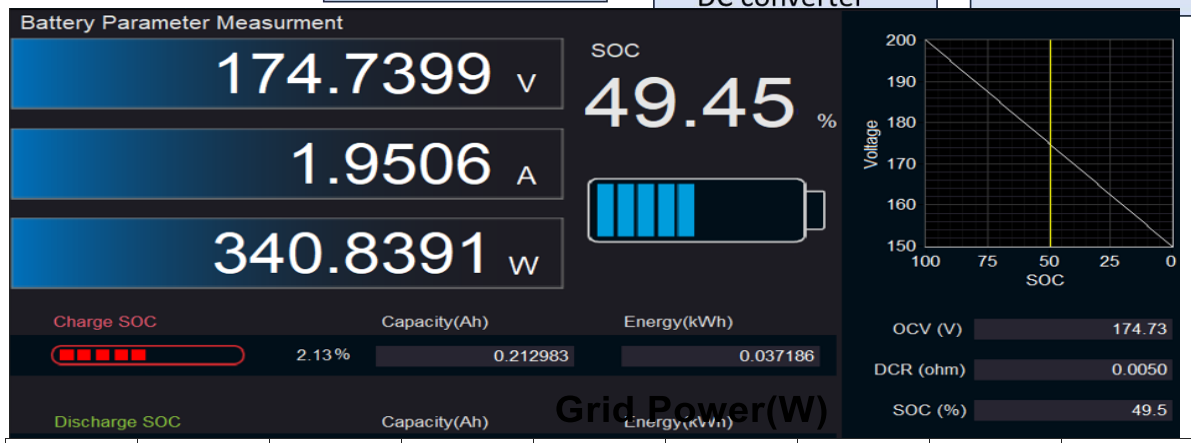

Battery Emulator


DC-DC converter

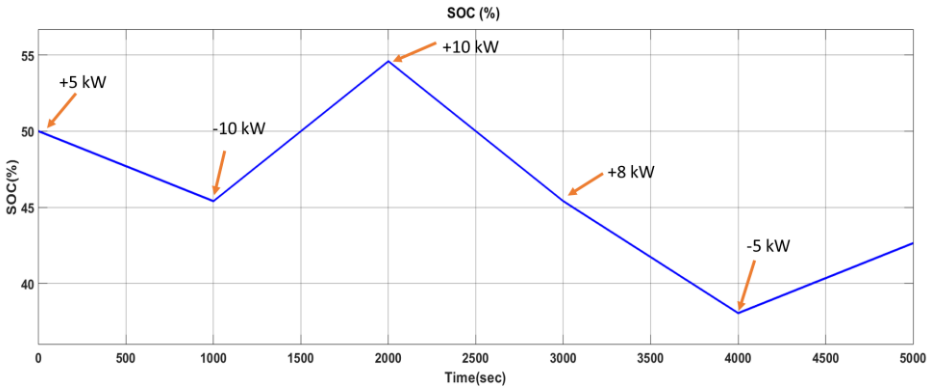

Bidirectional AC-DC converter

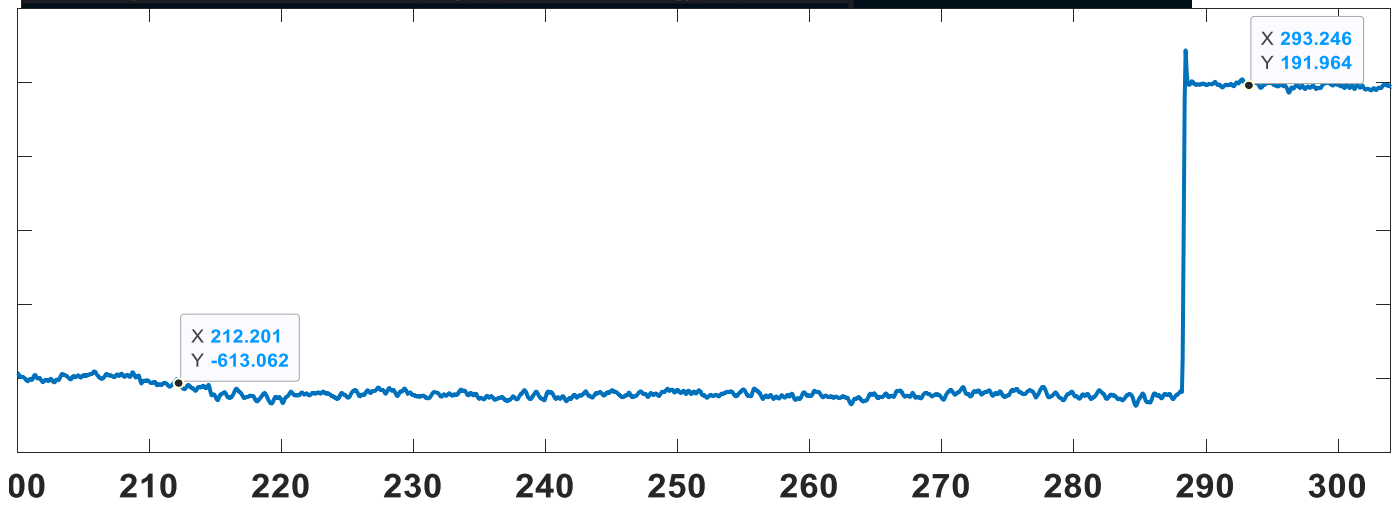

Filter


IEEE9 Bus

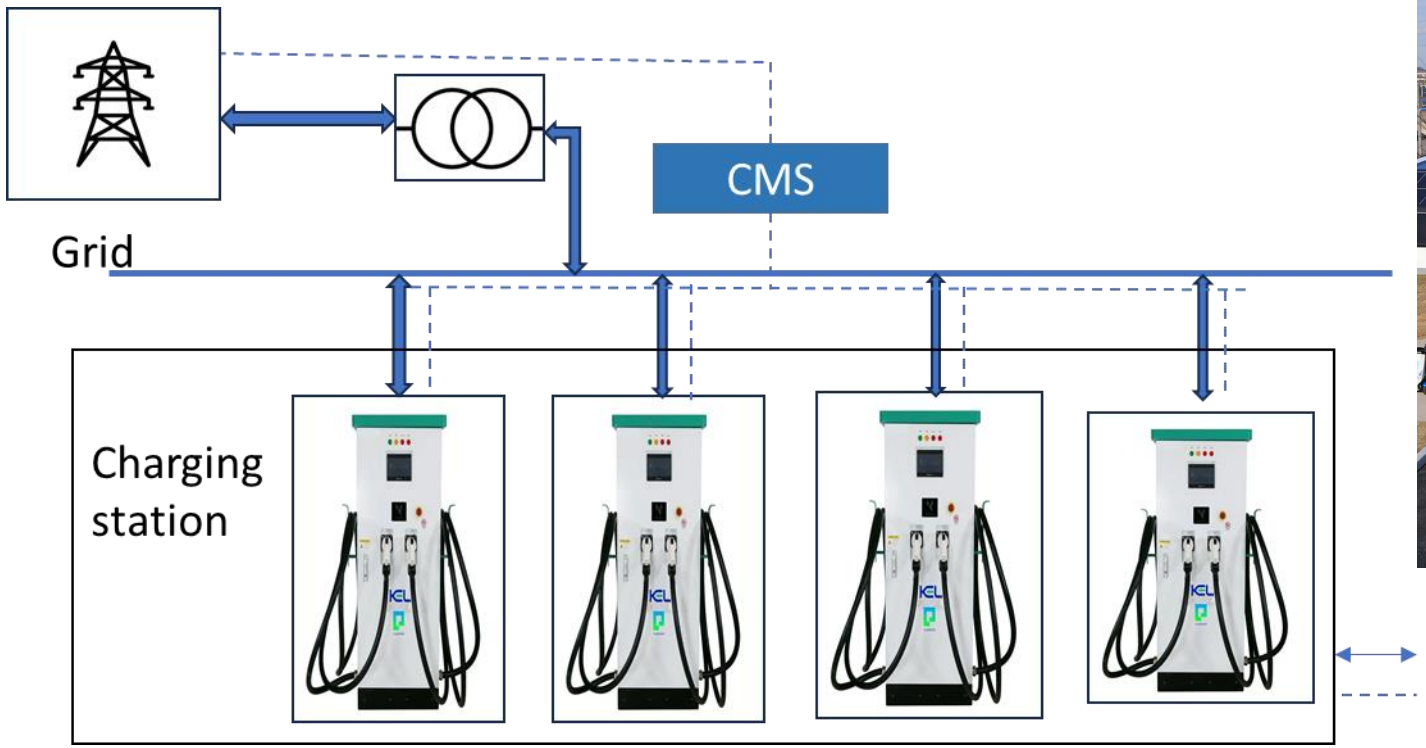


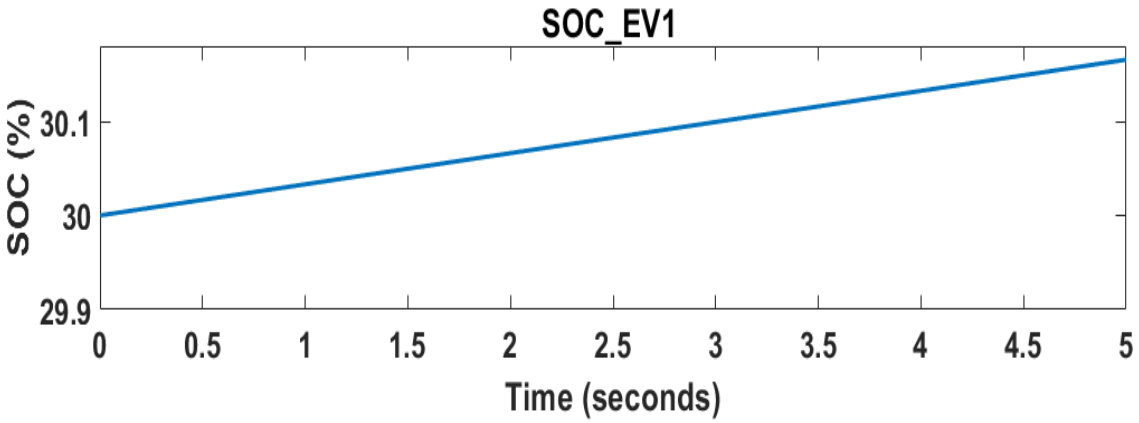

AC Load

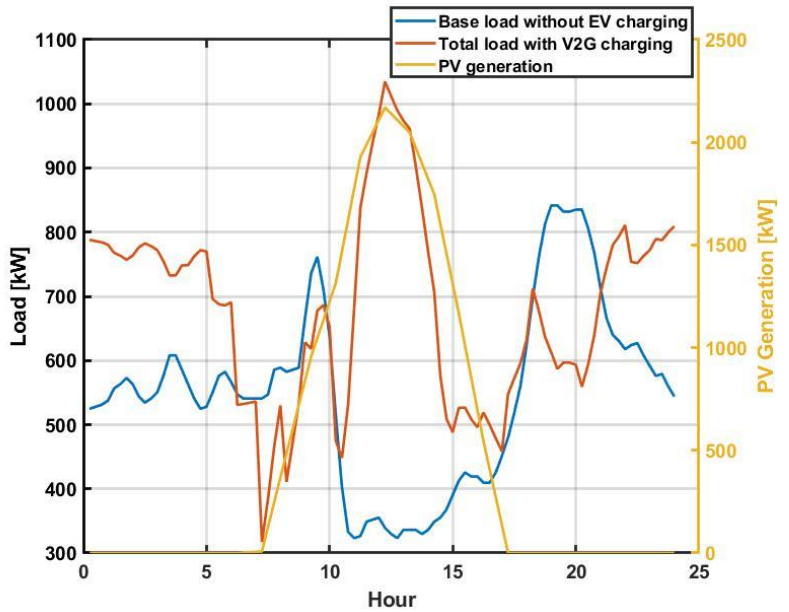




V2G Demonstration Pilot-2 in Pune







On behalf of:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

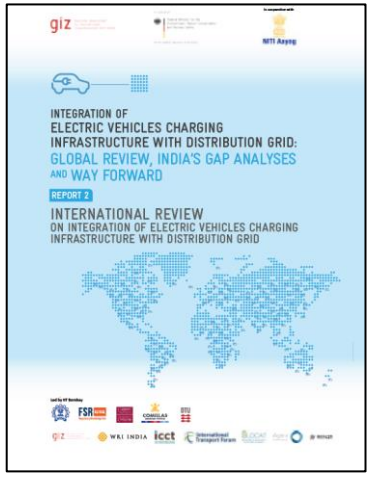
of the Federal Republic of Germany

In Cooperation with

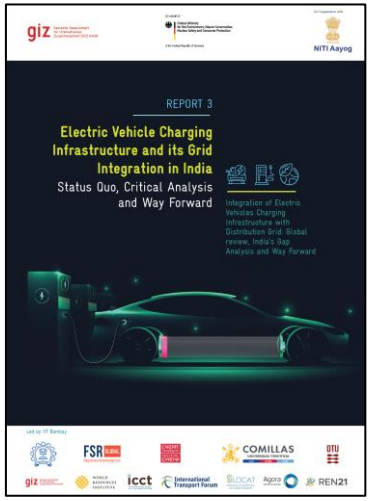
NITI Aayog

Some Relevant Reports on Grid Integration of EVs

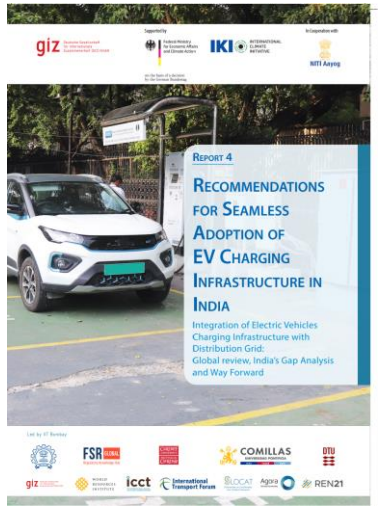
Fundamentals of Electric Vehicle Charging Technology and its Grid Integration



International review of Electric Vehicle Charging Infrastructure and its Grid Integration



Electric Vehicle Charging Infrastructure and its Grid Integration in India: Status Quo, Critical Analysis and Way Forward



Recommendations on Seamless Adoption of EV Charging Infrastructure in India

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THANK YOU

For discussions/suggestions/queries email: ***dum@indiasmartgrid.org***

www.isuw.in





Parker project

Project Category: Research and demonstration Project

Project duration: August 2016 to July 2018

Project aim: This project demonstrated the potential for EVs to provide grid frequency response services. Fifty charging points were provided by ENEL and the aggregation software by NUVVE

Project Overview:

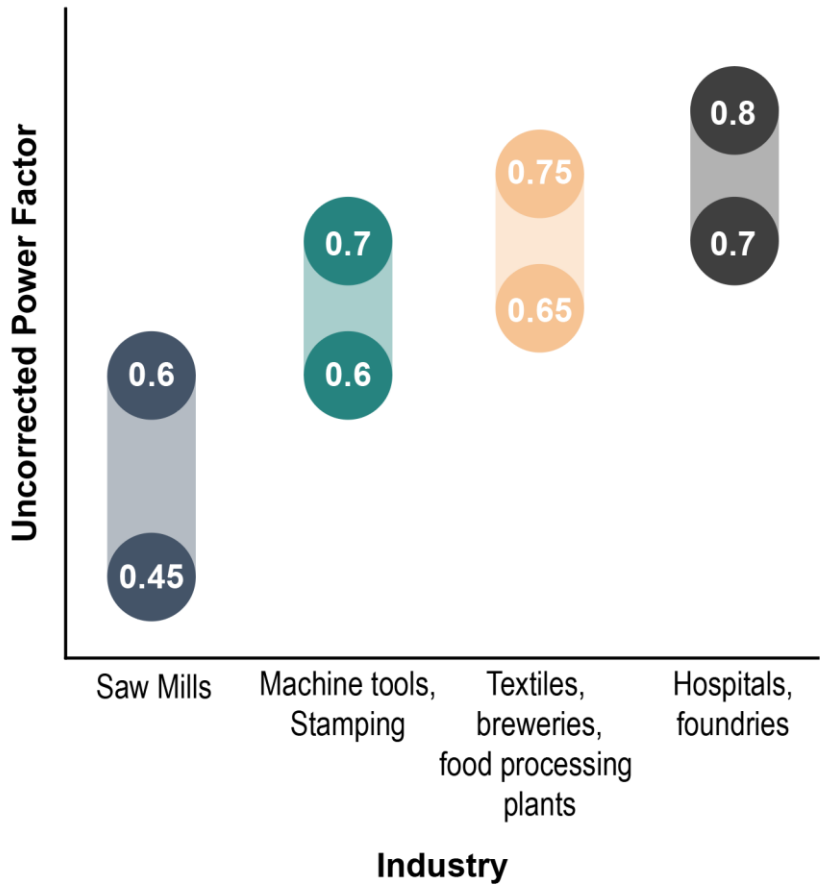
- Frequency-controlled normal operation reserve (FNR) is a service in which the contracted generation and load are continuously controlled to keep the frequency under stable operating limits.

- Hourly bids are submitted via the self-service portal of Energinet, the Danish national TSO.

- According to the Danish market regarding FNR only symmetrical bids are allowed, which means that the up and down regulation services must by provided together and the minimum bid for participation in the market is 0.3MW.

Use case-Reactive power support for food processing Industry in Delhi

Typical power factor ranges of a few industries



- Two major disadvantages of low power factors
  - Higher energy bill for the industry as more apparent power needs to be drawn for same amount of work.
  - Increases the net current flowing in the system, which may lead to overloading of different components.
- Industries employ different reactive power compensation techniques.

With industries already investing in electric vehicle charging stations, can this infrastructure be used for reactive power compensation?