# IMPACT OF ELECTRIC VEHICLES ON THE ELECTRICAL POWER GRID

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## Introduction

The increasing adoption of electric vehicles (EVs) is transforming the transportation sector due to their eco-friendliness, lower fuel dependency, and reduced maintenance costs. However, the mass adoption of EVs introduces significant challenges to power grids. Uncoordinated charging of EVs can lead to voltage instability, transformer overloads, and increased line losses, especially during peak demand periods.

This project aims to analyze these impacts and propose solutions to mitigate negative effects on the grid. The study primarily focuses on residential areas, shopping malls, and dedicated charging stations to understand their impact on power distribution networks. Furthermore, the project explores grid balancing techniques, including smart charging and demand response strategies.

## Mathematical Modelling and Analysis

### Power Demand Due to EV Charging

The total power demand due to EV charging can be calculated using:

$$P_{EV} = \frac{N \times Eev}{T}$$

where:

- $P_{EV}$ = Total power demand due to EV charging (kW)
- N = Number of EVs charging simultaneously
- Eev = Energy required per EV (kWh)
- T = Charging duration (hours)

### Voltage Drop in Distribution Network

EV charging can cause voltage drops, calculated using:

$$\Delta V = I \times Z$$

where:

- $\Delta V$ = Voltage drop (V)
- I = Charging current (A)
- Z = Line impedance ($\Omega$)

# Diagrams and Graphs

## System Diagrams:

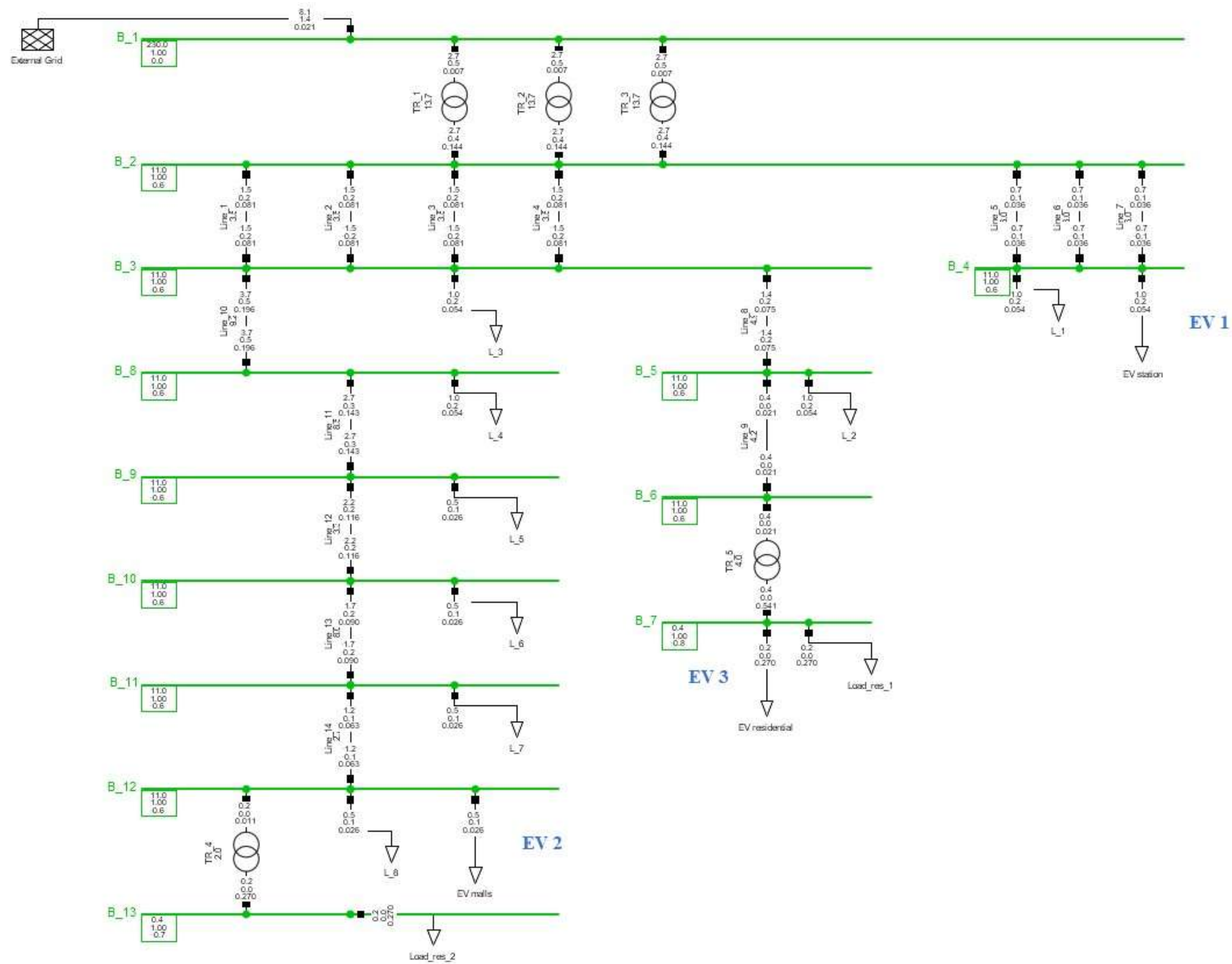
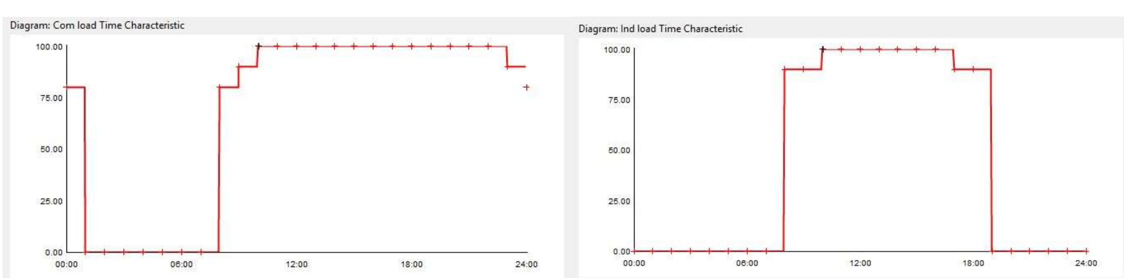
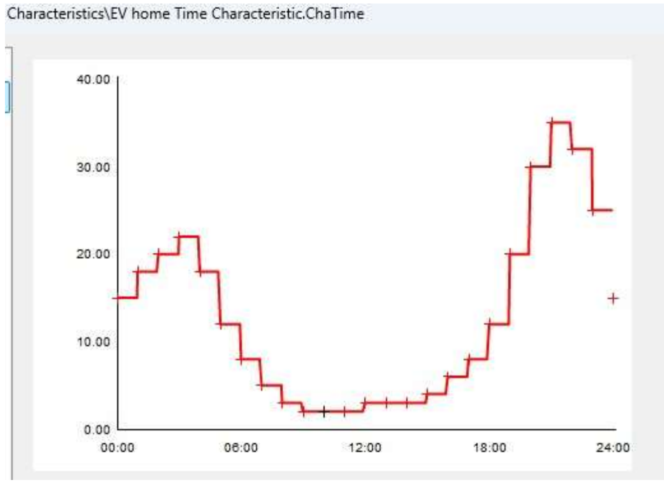



Fig 1:- System Diagram

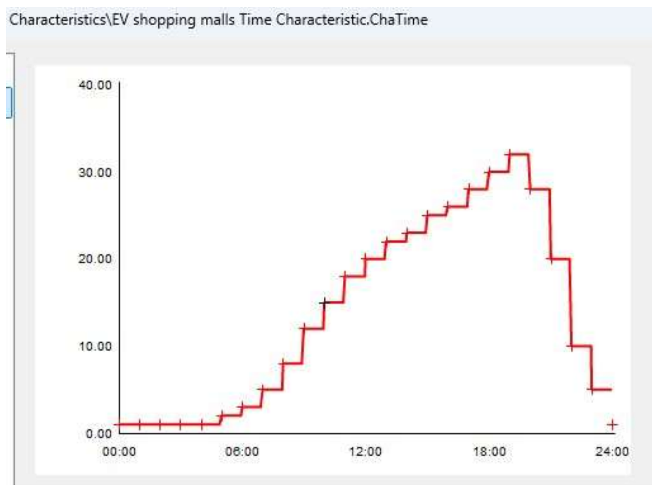



a) b)

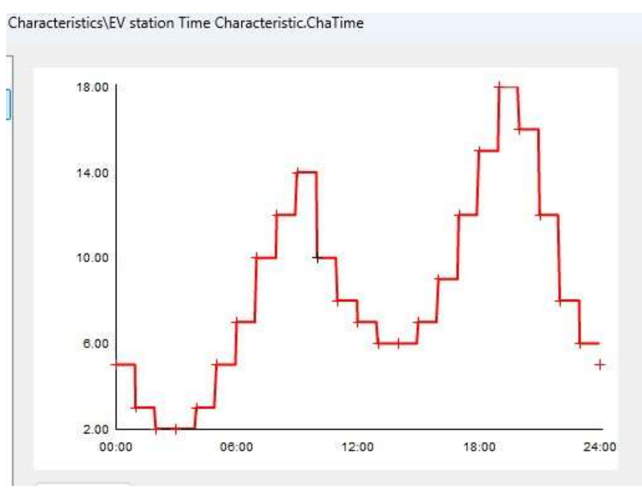
Fig 2:- Basic Non Constant a)Commercial and b)Industrial Loads




a)




b)




c)

Fig 3:- a) Residential b) Commercial c) Industrial

Load Curves without EV Load(s)

## **Voltage Deviation Due to EV Charging:**

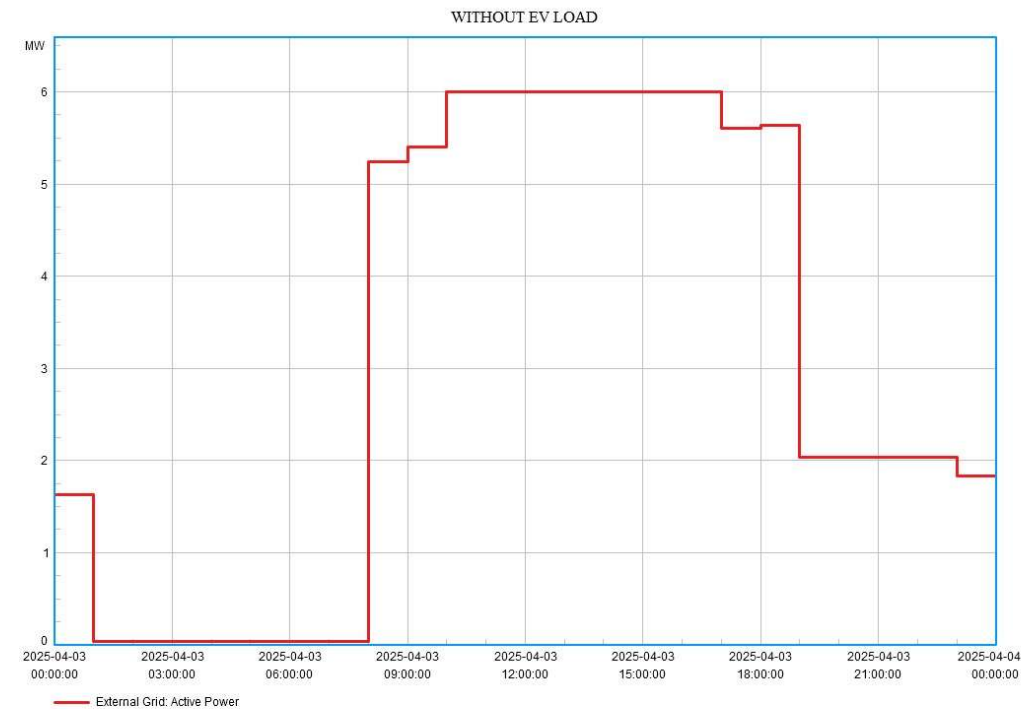



Fig 4: - Grid Power Without EV Load(s)

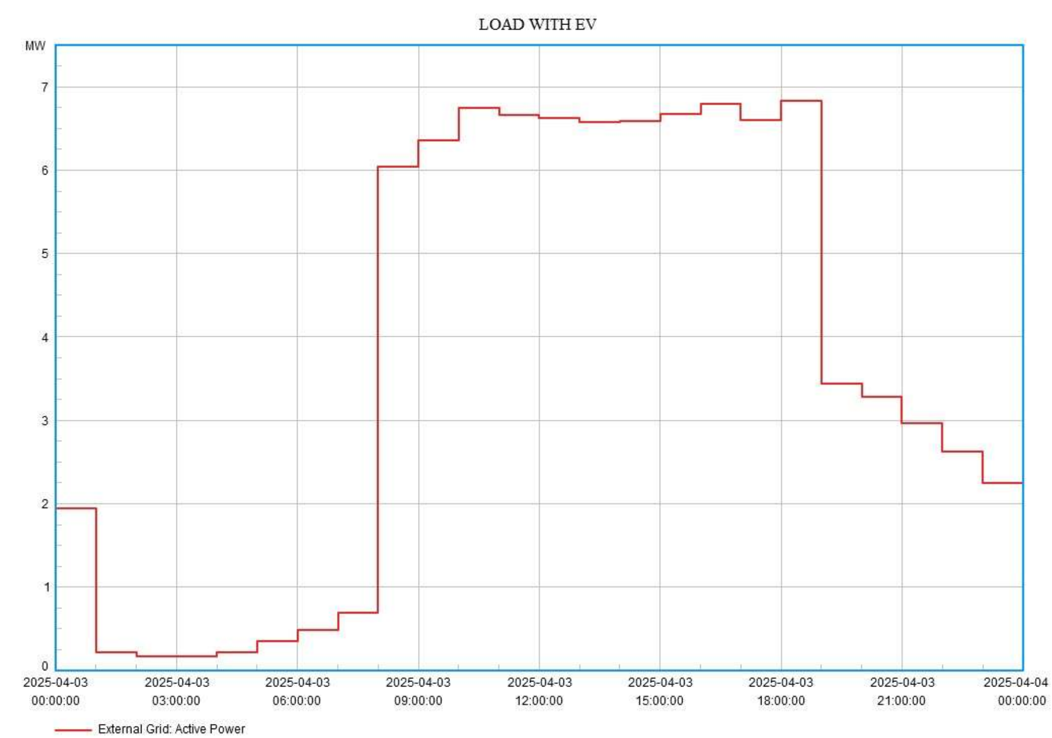
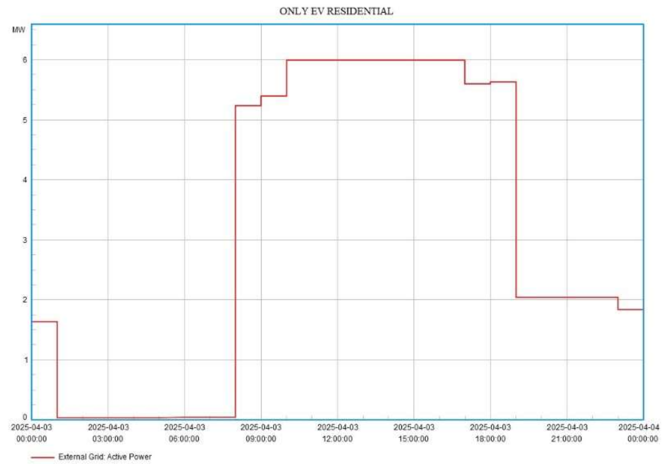
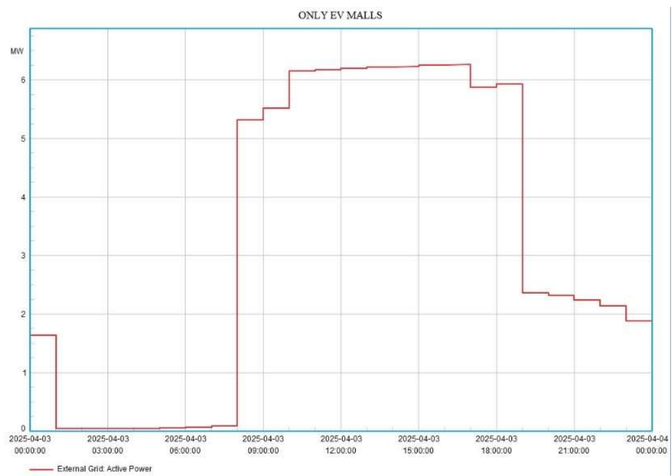


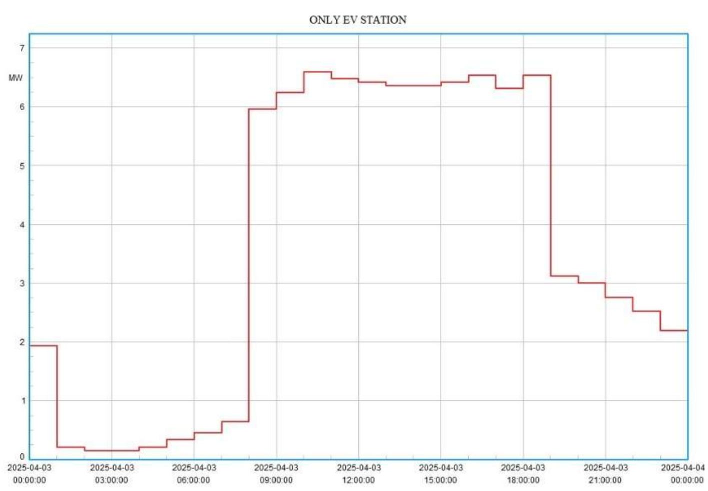

Fig 5: - Grid Power With EV Load(s)




a)



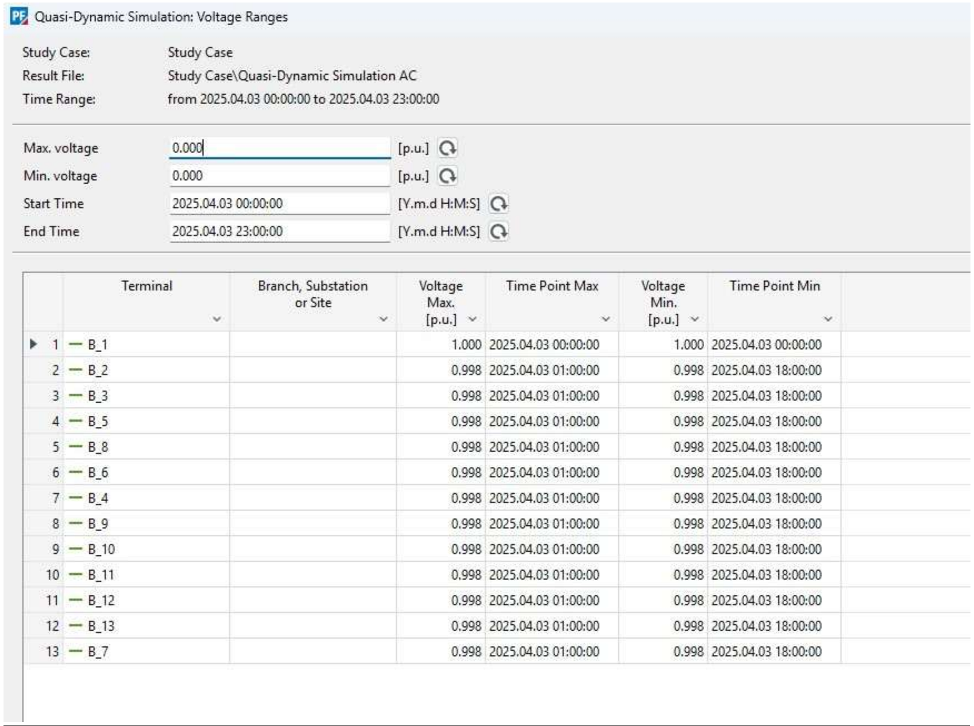

b)




c)

Fig 6:- a) Residential b) Commercial c) Industrial

Load Curves with EV Load(s)



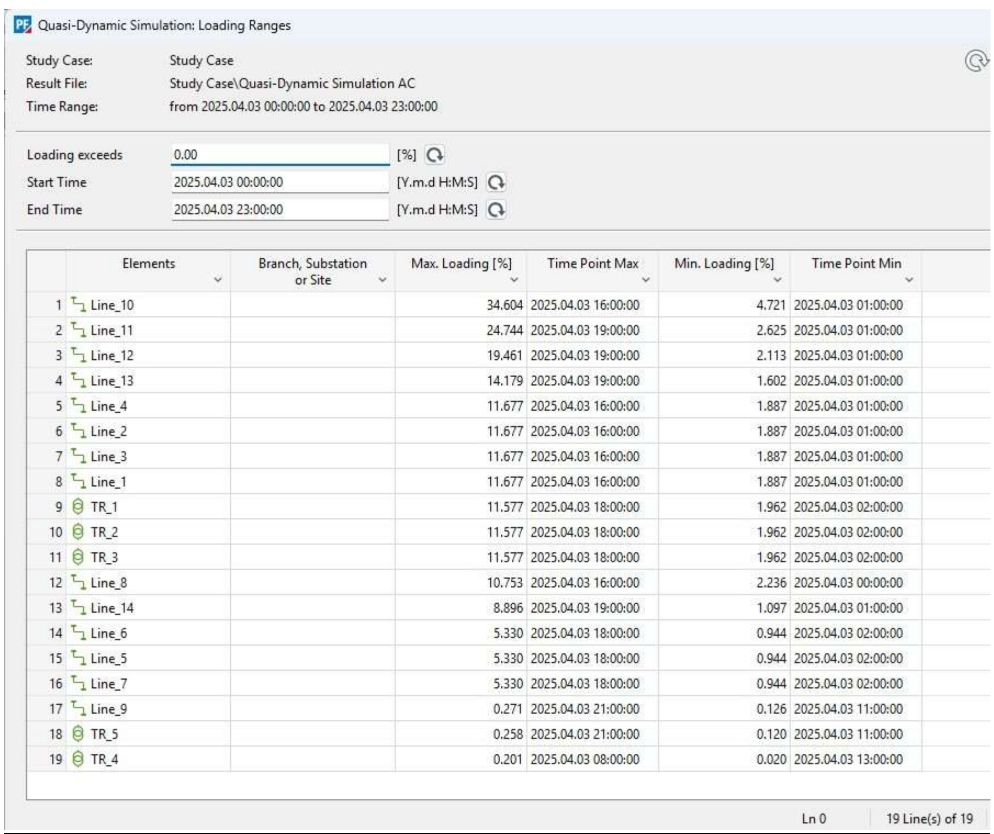
Quasi-Dynamic Simulation: Voltage Ranges

Study Case: Study Case
Result File: Study Case\Quasi-Dynamic Simulation AC
Time Range: from 2025.04.03 00:00:00 to 2025.04.03 23:00:00

Max. voltage 0.000 [p.u.]
Min. voltage 0.000 [p.u.]
Start Time 2025.04.03 00:00:00 [Y.m.d H:M:S]
End Time 2025.04.03 23:00:00 [Y.m.d H:M:S]

| | Terminal | Branch, Substation or Site | Voltage Max. [p.u.] | Time Point Max | Voltage Min. [p.u.] | Time Point Min |
|---|---|---|---|---|---|---|
| 1 | B_1 | | 1.000 | 2025.04.03 00:00:00 | 1.000 | 2025.04.03 00:00:00 |
| 2 | B_2 | | 0.998 | 2025.04.03 01:00:00 | 0.998 | 2025.04.03 18:00:00 |
| 3 | B_3 | | 0.998 | 2025.04.03 01:00:00 | 0.998 | 2025.04.03 18:00:00 |
| 4 | B_5 | | 0.998 | 2025.04.03 01:00:00 | 0.998 | 2025.04.03 18:00:00 |
| 5 | B_8 | | 0.998 | 2025.04.03 01:00:00 | 0.998 | 2025.04.03 18:00:00 |
| 6 | B_6 | | 0.998 | 2025.04.03 01:00:00 | 0.998 | 2025.04.03 18:00:00 |
| 7 | B_4 | | 0.998 | 2025.04.03 01:00:00 | 0.998 | 2025.04.03 18:00:00 |
| 8 | B_9 | | 0.998 | 2025.04.03 01:00:00 | 0.998 | 2025.04.03 18:00:00 |
| 9 | B_10 | | 0.998 | 2025.04.03 01:00:00 | 0.998 | 2025.04.03 18:00:00 |
| 10 | B_11 | | 0.998 | 2025.04.03 01:00:00 | 0.998 | 2025.04.03 18:00:00 |
| 11 | B_12 | | 0.998 | 2025.04.03 01:00:00 | 0.998 | 2025.04.03 18:00:00 |
| 12 | B_13 | | 0.998 | 2025.04.03 01:00:00 | 0.998 | 2025.04.03 18:00:00 |
| 13 | B_7 | | 0.998 | 2025.04.03 01:00:00 | 0.998 | 2025.04.03 18:00:00 |

a)



Quasi-Dynamic Simulation: Loading Ranges

Study Case: Study Case
Result File: Study Case\Quasi-Dynamic Simulation AC
Time Range: from 2025.04.03 00:00:00 to 2025.04.03 23:00:00

Loading exceeds 0.00 [%]
Start Time 2025.04.03 00:00:00 [Y.m.d H:M:S]
End Time 2025.04.03 23:00:00 [Y.m.d H:M:S]

| | Elements | Branch, Substation or Site | Max. Loading [%] | Time Point Max | Min. Loading [%] | Time Point Min |
|---|---|---|---|---|---|---|
| 1 | Line_10 | | 34.604 | 2025.04.03 16:00:00 | 4.721 | 2025.04.03 01:00:00 |
| 2 | Line_11 | | 24.744 | 2025.04.03 19:00:00 | 2.625 | 2025.04.03 01:00:00 |
| 3 | Line_12 | | 19.461 | 2025.04.03 19:00:00 | 2.113 | 2025.04.03 01:00:00 |
| 4 | Line_13 | | 14.179 | 2025.04.03 19:00:00 | 1.602 | 2025.04.03 01:00:00 |
| 5 | Line_4 | | 11.677 | 2025.04.03 16:00:00 | 1.887 | 2025.04.03 01:00:00 |
| 6 | Line_2 | | 11.677 | 2025.04.03 16:00:00 | 1.887 | 2025.04.03 01:00:00 |
| 7 | Line_3 | | 11.677 | 2025.04.03 16:00:00 | 1.887 | 2025.04.03 01:00:00 |
| 8 | Line_1 | | 11.677 | 2025.04.03 16:00:00 | 1.887 | 2025.04.03 01:00:00 |
| 9 | TR_1 | | 11.577 | 2025.04.03 18:00:00 | 1.962 | 2025.04.03 02:00:00 |
| 10 | TR_2 | | 11.577 | 2025.04.03 18:00:00 | 1.962 | 2025.04.03 02:00:00 |
| 11 | TR_3 | | 11.577 | 2025.04.03 18:00:00 | 1.962 | 2025.04.03 02:00:00 |
| 12 | Line_8 | | 10.753 | 2025.04.03 16:00:00 | 2.236 | 2025.04.03 00:00:00 |
| 13 | Line_14 | | 8.896 | 2025.04.03 19:00:00 | 1.097 | 2025.04.03 01:00:00 |
| 14 | Line_6 | | 5.330 | 2025.04.03 18:00:00 | 0.944 | 2025.04.03 02:00:00 |
| 15 | Line_5 | | 5.330 | 2025.04.03 18:00:00 | 0.944 | 2025.04.03 02:00:00 |
| 16 | Line_7 | | 5.330 | 2025.04.03 18:00:00 | 0.944 | 2025.04.03 02:00:00 |
| 17 | Line_9 | | 0.271 | 2025.04.03 21:00:00 | 0.126 | 2025.04.03 11:00:00 |
| 18 | TR_5 | | 0.258 | 2025.04.03 21:00:00 | 0.120 | 2025.04.03 11:00:00 |
| 19 | TR_4 | | 0.201 | 2025.04.03 08:00:00 | 0.020 | 2025.04.03 13:00:00 |

Ln 0 19 Line(s) of 19

b)

Fig 7: - Quasi-Dynamic Simulation: a) Voltage and b) Loading Ranges

## Results and Discussion

1. Simulation & Analysis:
    - A Monte Carlo-based EV charging model was developed to assess various charging scenarios.
    - Quasi-dynamic simulations in DigSILENT PowerFactory evaluated the impact on line loading, transformer capacity, and voltage stability over a 24-hour period.
2. Findings:
    - Higher EV penetration led to transformer overheating and increased voltage drops.
    - Optimized placement of charging stations helped distribute load effectively.
    - Off-peak charging incentives improved grid stability by shifting charging loads to non-peak hours.
    - Smart charging algorithms reduced peak demand by 15%-20%.

## Mitigation Strategies

1. Smart Charging Algorithms: Load shifting and controlled charging reduce stress on grid components.
2. Vehicle-to-Grid (V2G) Integration: Allows EVs to supply power back to the grid, improving stability.
3. Renewable Energy Integration: Utilizing solar and wind power to supplement EV charging demands.
4. Infrastructure Upgrades: Reinforcing transformers and distribution lines to handle additional loads.

## Conclusion

The study concludes that while current EV adoption levels have a manageable impact on the grid, increasing penetration will demand proactive planning. The developed model provides valuable insights into grid performance under different EV charging conditions. Recommendations such as optimal charger placements, grid upgrades, and time-based incentives are crucial for sustainable EV integration. The flexibility of this model makes it applicable across various regions, assisting energy companies and investors in long-term planning.

## Individual Contributions

Harikishanthini K: - Simulation and Report Writing

Shruthi Ramprasad: - Literature Review and Report Writing

Ishani Dey: - Presentation and Report Writing

## References


- **Investigation on The Electrical Vehicles Effects on The Electrical Power Grid, Meral KILIÇARSLAN OUACH1a, Ertuğrul ÇAM1b,** 1Kırıkkale Üniversitesi, Mühendislik Fakültesi, Elektrik-Elektronik Mühendisliği Bölümü. 71450, Kırıkkale/TÜRKİYE
- **Impact of Electric Vehicle Integration on an Industrial Distribution Network: Case Study Based on Recent Standards -** Ana Simarro-Garc´ıa, Raquel Villena-Ruiz, Andr´es Honrubia-Escribano, Emilio G´omez-L´azaro.