P2P Markets to Support Trading in Smart Grids with Electric Vehicles

Diogo Antunes[1,2], **Tiago Soares**[3,4], **and Hugo Morais**[1,2]

[1] Dept. of Electrical and Computer Engineering, Instituto Superior Técnico, Lisboa, Portugal. [2] INESC Research and Development (INESC ID), Lisboa, Portugal, [3]INESC Technology and Science (INESC TEC), Porto, Portugal, [4] Faculty of Engineering, University of Porto, Porto, Portugal

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INTRODUCTION

As energy systems evolve, protecting and empowering consumers is vital, enabling participation in decentralized electricity markets and maximizing benefits from energy resources. The integration of Distributed Energy Resources (DER) and Renewable Energy Sources (RES) fosters new energy communities, shifting from centralized systems to distributed structures. Consumers can sell excess production to neighbors, increasing income, reducing bills, and advancing energy transition goals. This poster proposes a community-based peer-to-peer (P2P) energy market model that reduces costs while respecting network constraints. Using the Alternating Direction Method of Multipliers (ADMM), ensures privacy enhancement, decentralization, and scalability. The Relaxed Branch Flow Model (RBFM) manages constraints, and Electric Vehicles (EVs) reduce imports and costs through strategic discharging. Tested on a 33-bus distribution network, the ADMM-based approach aligns closely with a centralized benchmark, showing minor discrepancies while maintaining system reliability. This model underscores the potential of decentralized markets for consumer-centric, flexible, and efficient energy trading.

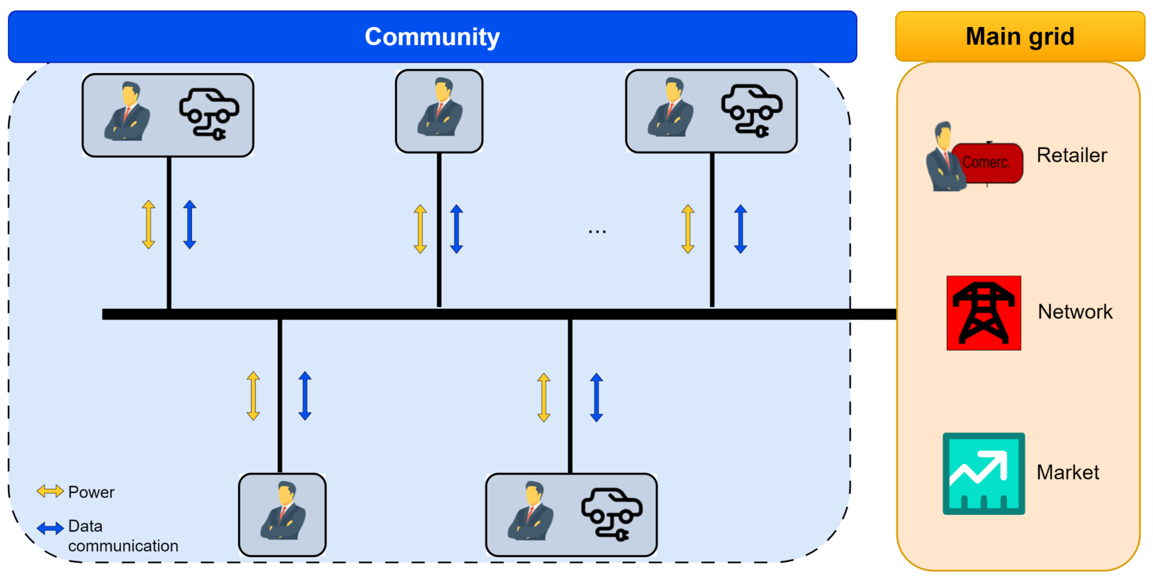

Figure 1 Energy community's distributed architecture.

Network and Input Data

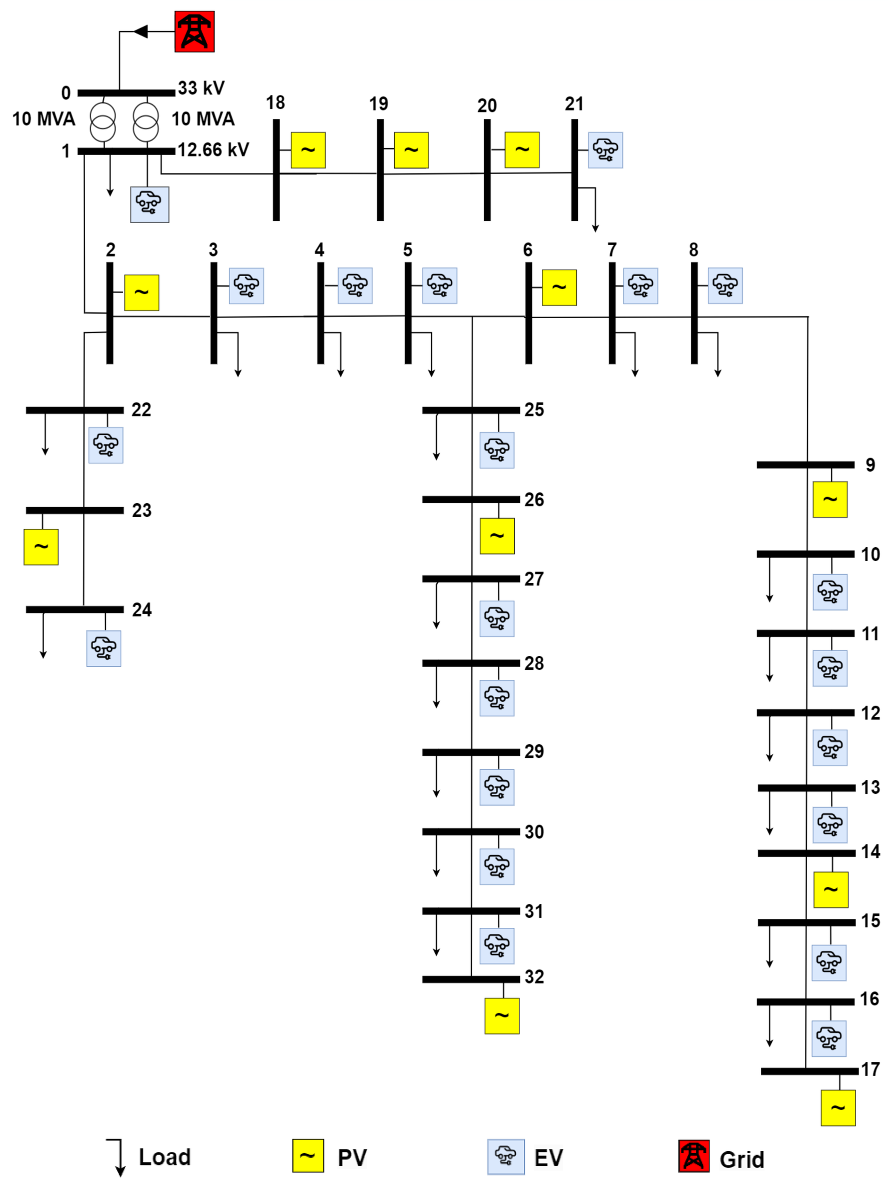

Figure 2 33-bus radial distribution network.

- **33-bus** medium-voltage (MV) radial distribution network
- Nominal voltage: **12.66 kV**
- 1 connection to the TSO network
- **11** PV systems
- **21** community consumers, each owning 1 EV (total of 21 EVs)
- Real MIBEL market prices for import pricing
- Import bids set at 85% of MIBEL import prices
- Import prices from September 19, 2024

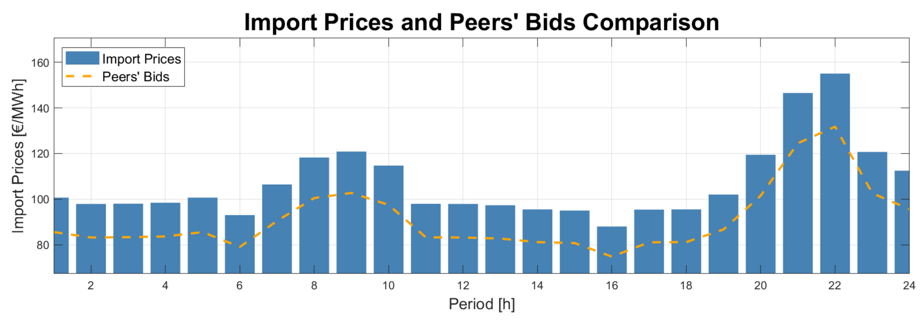

Figure 3 MIBEL day-ahead hourly prices.

Network-constrained P2P Markets with EVs

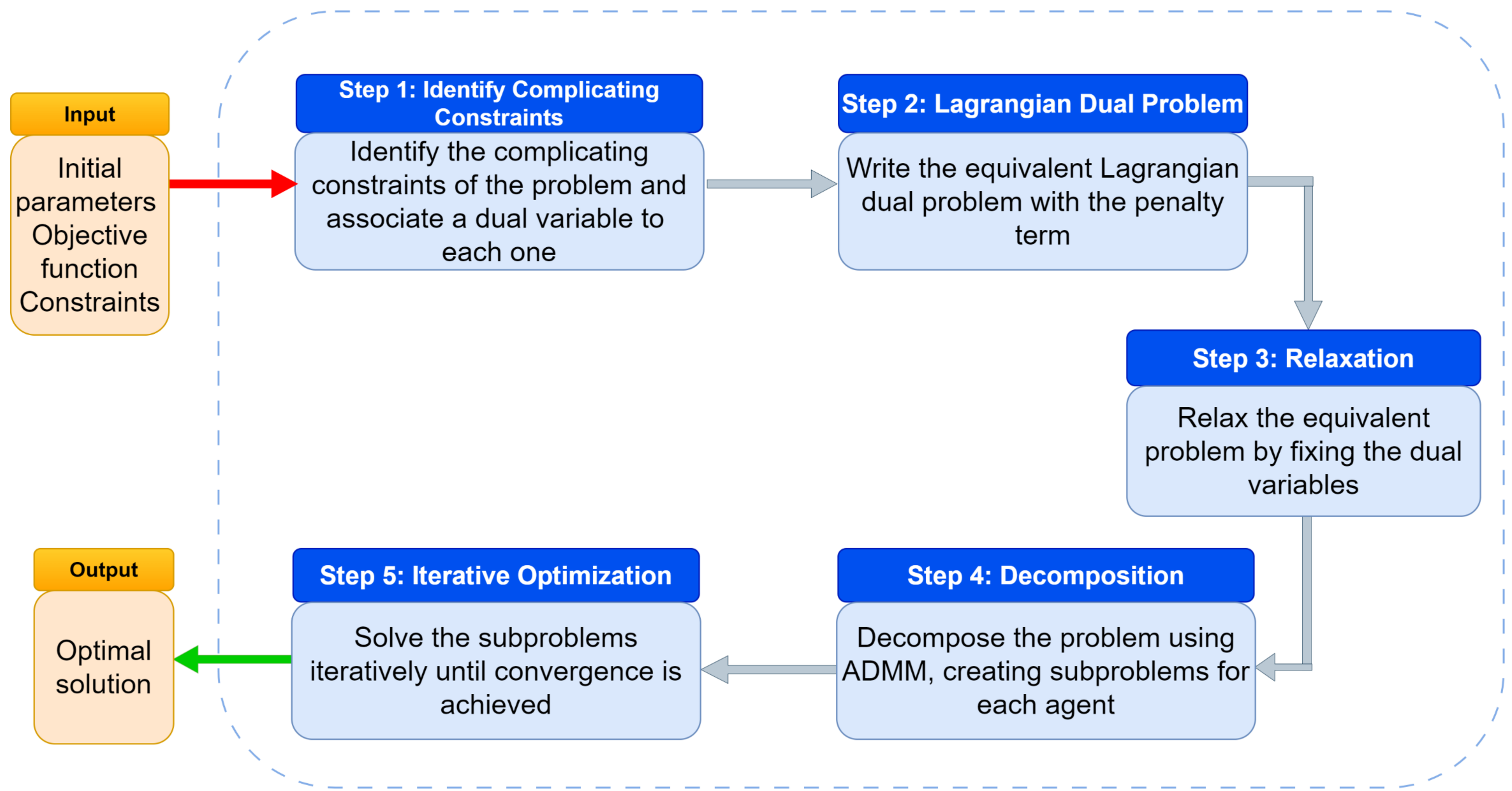

Figure 4 Decomposition technique - ADMM for distributed optimization.

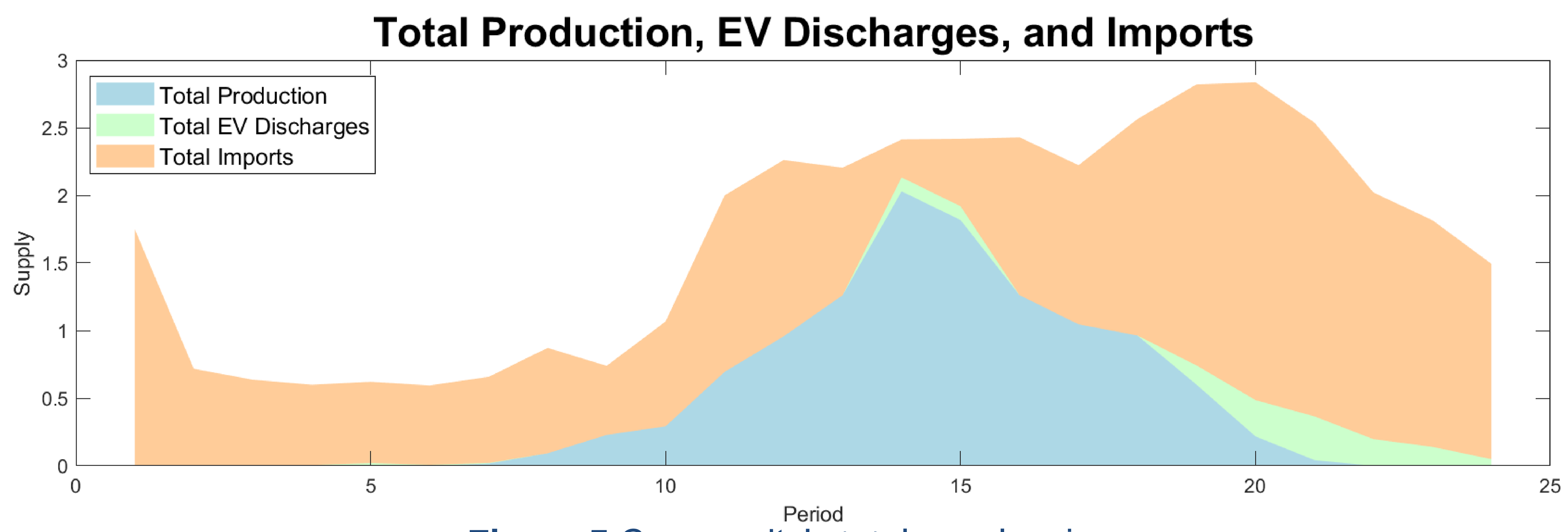

Figure 5 Community's total supply mix.

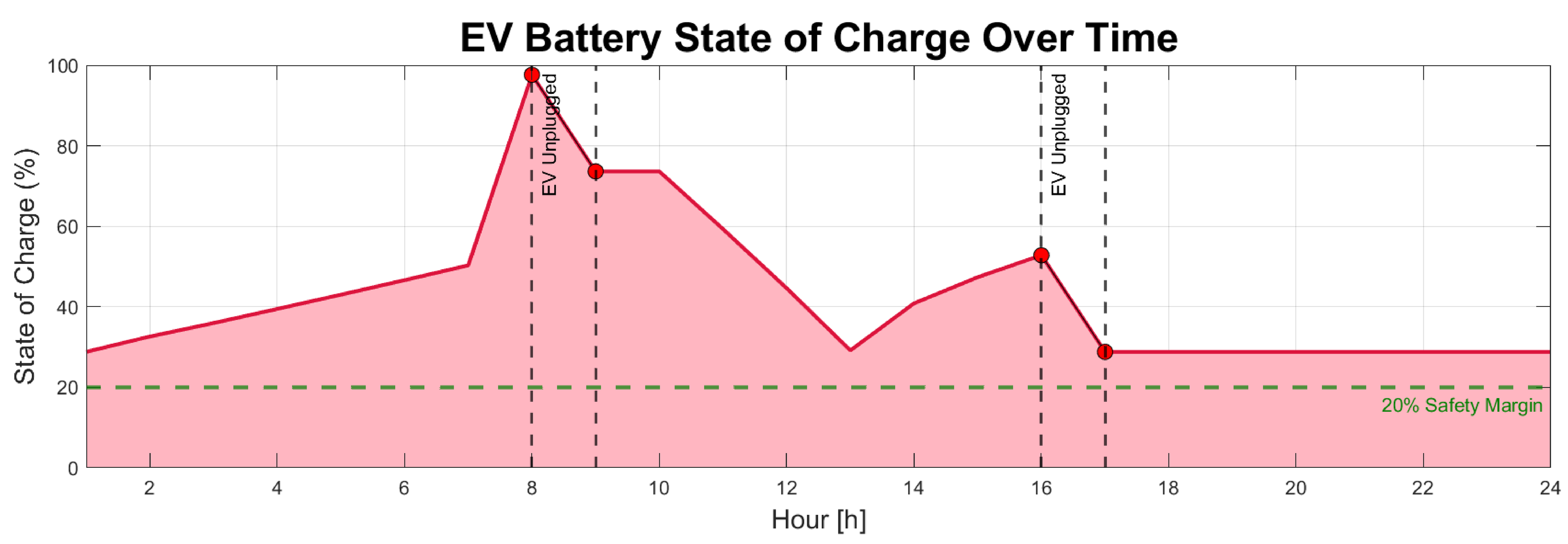

Figure 6 EV battery state-of-charge evolution over simulation time.

ADMM Performance

- ADMM **matched** centralized model results
- Supply and demand **balanced**
- Voltage limits maintained
- EVs discharged 0.47 MW (**3.75%** of imports) at peak
- Decentralized optimization with **minimal data sharing**

- **1169 iterations**, **3927 seconds** to converge
- Penalty parameter: **100** | Tolerance: $\mathbf{1 \times 10^{-4}}$
- High computational effort
- Without **Residual Balance**, convergence not always reached (limit: 20,000 iterations)
- RB improved efficiency and reduced computation time

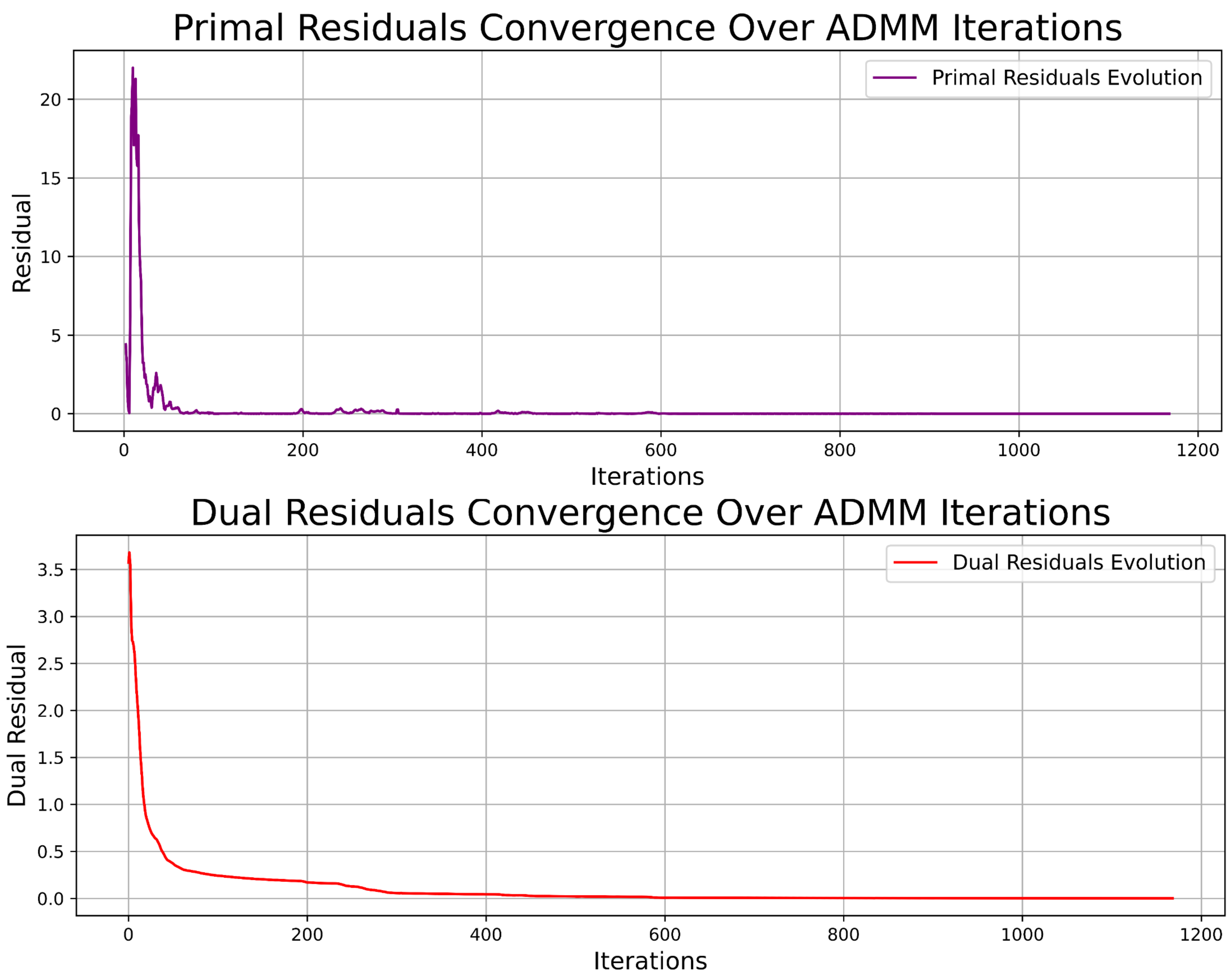

Figure 7 Primal and dual residuals convergence over ADMM iterations on a 33-nodes network.

CONCLUSIONS

- In this study, a distributed ADMM-based model is explored for P2P market clearing under network constraints in a 33-node community with PVs and EVs.
- The ADMM model achieves results closely aligned with a centralized benchmark, showing only a 9.12% relative error and stable voltage profiles.
- Demonstrates scalability, reduced communication overhead, and enhanced participant privacy.
- EVs play a dual role by discharging during peak demand periods, reducing imports and lowering community energy costs.
- Enables efficient local energy trading—consumers buy at lower prices than import price, while producers earn more than traditional FiT schemes.
- ADMM solves smaller subproblems independently, reducing reliance on a central entity.

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