Case Study: Decentralized Peer-to-Peer Energy Trading for a Residential Community

1. Introduction

The transition toward decentralized energy systems has gained significant attention in recent years, driven by the increasing adoption of renewable energy sources and advancements in blockchain technology. Traditional centralized electricity markets often face transmission losses, grid congestion, and inefficient pricing mechanisms. In contrast, decentralized peer-to-peer (P2P) energy trading offers an innovative solution by enabling households to trade surplus energy directly, thereby optimizing local energy utilization and reducing reliance on the main power grid.

This case study explores a decentralized P2P energy trading system within a residential community consisting of ten households. The study is inspired by the blockchain-based approach proposed in [1], which highlights the potential of secure and verifiable transactions in energy markets. Unlike the original study, this case does not incorporate battery storage, heat pumps, or electric vehicle charging, simplifying the initial setup while maintaining the core principles of P2P energy trading. By leveraging a blockchain-based trading platform, households can autonomously buy and sell electricity, ensuring efficiency, transparency, and cost-effectiveness.

2. Data and Methodology

2.1 Dataset Description

The dataset used for this study originates from a single residential household, covering a period of nearly five years (2014–2020) [2]. This dataset consists of 201,604 records collected at 15-minute intervals. To streamline the analysis, we extract only the most recent year of data and include three primary variables:

- **Electricity Load**: The total electricity consumption of the household.
- **Residential Wind Generation**: The energy produced by wind turbines installed at the household.
- **Residential Solar Generation**: The energy produced by solar photovoltaic (PV) panels.

To model a community of ten households, we generate synthetic data for the remaining nine households by scaling the original dataset according to predefined scaling factors. This approach maintains the variability and temporal characteristics of the original dataset while allowing for community-wide analysis. The scaling factors applied to the original dataset to create the synthetic households are presented in Table I.

2.2 Synthetic Data Generation

Table I presents the scaling factors used for each household. The original dataset values, denoted as X, are scaled by multiplicative factors to introduce variation across households while preserving realistic consumption and generation profiles.

Table I: Synthetic Data Generation for Residential Community

Dataset	Electricity Load	Residential Wind Generation	Residential Solar Generation
0	X	X	X
1	X	-	X
2	X	X	-
3	X (× 0.8)	-	-
4	X (× 0.6)	-	-
5	X (× 1.2)	-	-
6	X (× 0.8)	-	X (× 0.7)
7	X (× 0.6)	X (× 1.1)	-
8	X (× 1.2)	-	X (× 0.9)
9	X (× 1.0)	X (× 0.8)	-

The table highlights the variability in energy consumption and renewable generation among households, providing a diverse yet realistic data set for simulation.

Based on this distribution, the case study community consists of seven prosumers (households that both consume and generate electricity) and three consumers (households that only consume electricity without generating any renewable energy), as we can see in Figure 1.

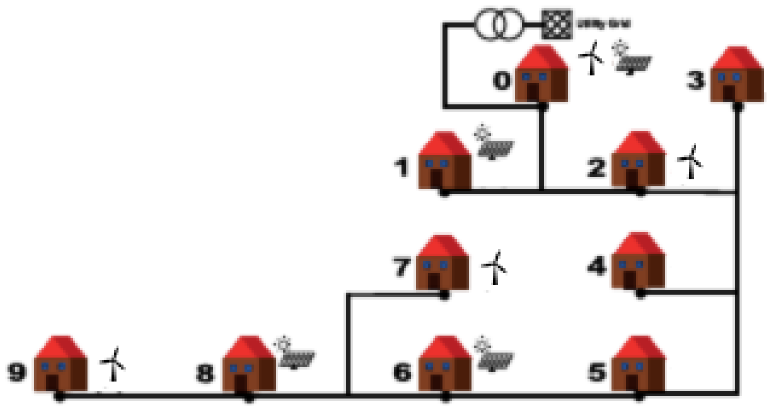

Figure 1-Topology and distribution of households

3. System Model and Trading Mechanism

Each household in the community operates as an independent agent capable of buying and selling electricity through a decentralized trading platform. The blockchain network ensures secure and verifiable transactions, preventing the need for centralized control. Energy trading follows two core strategies:

- **Supply-Demand Matching Strategy (ST1):** Households with energy surpluses prioritize trading with households experiencing deficits based on real-time demand and supply conditions.
- **Distance-Based Matching Strategy (ST2):** Households prioritize trading with their closest neighbors, reducing transmission losses and enhancing local energy utilization.

The trading algorithm ensures market equilibrium by dynamically adjusting prices based on supply and demand interactions to minimize costs and optimize energy self-consumption.

4. Simulation and Results

A numerical evaluation is performed to assess the effectiveness of the P2P trading system. Key performance indicators include:

- **Reduction in Grid Dependency:** The percentage of locally generated energy consumed within the community.
- **Trading Volume:** The amount of energy exchanged between households.
- **Economic Benefits:** Cost savings achieved by households through P2P transactions compared to purchasing from the main grid.

References

[1] T. AlSkaif, J. L. Crespo-Vazquez, M. Sekuloski, G. van Leeuwen, and J. P. S. Catalão, “Blockchain-Based Fully Peer-to-Peer Energy Trading Strategies for Residential Energy Systems,” *IEEE Trans. Ind. Inform.*, vol. 18, no. 1, pp. 231–241, 2022, doi: 10.1109/TII.2021.3077008.

[2] M. W. Wijesooriya, “Residential Load Consumption, Electricity price, Renewable Energy Generation DATA Set in the UK.” IEEE DataPort. doi: 10.21227/MBTN-ZT12.

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