“P2P TRADING USING DERs: A HOLISTIC VIEW OF GLOBAL PRACTICES AND PIONEERING EFFORTS IN INDIA”

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Dynamically changing power system paradigm

Changing from centralized system to Decentralized System

Distributed Energy Resources
- Rooftop Solar
- Electric Vehicles
- Demand Response
- Storage
- Wind

Emerging scenario
- Emergence of DERs
- Renewable generation technologies on distribution and transmission networks
- Local battery storage deployment
- Smart homes and smart grids
Peer To Peer (P2P) Energy Trading:-

- Enables prosumers to **receive instant payment** from renewable energy
- Customers can buy **cheaper renewable energy**
- **Competitive advantage** for innovative retailers
- Transparent, secure and instant electricity transactions by Distributed Ledger Technology
- Better return for excess energy as compared to supplying it to grid.
- Allows for more **informed usage decisions**
Net Metering v/s Peer to Peer (P2P) Trading (Power Flow):

**Case 1:**
- **Net Metering**
  - Low AT&C losses.
  - Demand gets completed locally.

**DISCOM:**
- Trade Energy within community.
- Cheaper than Retail tariff.
- Instant Payment and settlement

**Case 2:**
- **Peer to Peer (P2P) Trading**
  - ITxaction fee given by the peers.

**Peers:**
- Trade Energy within community.
- Cheaper than Retail tariff.
- Instant Payment and settlement
Net Metering v/s Peer to Peer (P2P) Trading (Cash Flow):-

Case 1:-
Net Metering

Case 2:-
Peer to Peer (P2P) Trading

APPc Rate

Feed in Tariff

Cash Flow
Physical Infrastructure

Market Clearing Price
Why Blockchain?

**A consumer and a prosumer agree for a transaction**

The transaction is combined with other transactions made during the same timestamp to create a new block.

**Source:** PwC
Smart Contracts & Energy Tokens:-

- Rules/algorithms which can signal the system
- Initiate certain transactions
- Payments in the microgrid between peers
- Manage Grid Congestion
- Balance between supply and Demand
- Network Flows

Agent Bidding Strategies
• Random Bidding Strategy
• Preference Bidding Strategy

Auction Mechanism
• Discriminatory k-DA
• Uniform k-DA

Economic Efficiency Evaluation Matrix
• Percentage of kWh Sold
• Percentage of kWh Bought
• Percentage of Household cleared

Unit is published by seller/buyer in the network.
Smart contracts gets activated

Bidding Strategy
Auction Mechanism

Calculates Clearing Price
Tokens get transferred

Transaction gets completed
Economic efficiency evaluation matrix
1. Auction Mechanism:-

**Discriminatory k-Double Auction**

- C – Consumers and \( C_p \) - Asking Price
- P – Prosumers and \( P_p \) - Selling Price
- Asking Price – Ascending order
- Selling Price - Descending order
- The trading will happen only when the buying price is always greater than or equal to the selling price (\( C_p \geq P_p \))

\[
P = kC_p + (1-k) P_p
\]

- This process is entirely discriminatory as the “P” i.e. trading price is always between every winning prosumers-consumer pair.

**Uniform k-Double Auction**

- \( C_y \) – Consumers and \( C_{py} \) - Asking Price
- \( P_y \) – Prosumers and \( P_{py} \) - Selling Price
- Asking Price – Ascending order
- Selling Price - Descending order
- Here, all the winning consumers and prosumers trade at a common clearing price.
- Next, “Y” is considered as the largest breakdown index taking the Yth consumer and prosumers.

\[
P = kC_{py} + (1-k) P_{py}
\]

- Therefore, we get a distinct per unit transaction trading price for all winning consumer and prosumers at each 30 minute interval.

<table>
<thead>
<tr>
<th>K Value [0,1]</th>
<th>Condition</th>
</tr>
</thead>
</table>
| 1             | P is equal to the Asking Price  
If \( C_p \geq P_p \), the prosumers increases a utility of \( C_p - P_p \) as the prosumers received additional than the estimated price. |
| 0.5           | It sets the “P” at precisely between the buying price and the selling price. None of the party escalates more utility than the other. |
| 0             | P is equal to the Selling Price.  
If \( C_p \geq P_p \), the consumer increases a utility of \( C_p - P_p \) as the consumer trades at a lower than anticipated price. |
## 2. Economic Efficiency Evaluation Matrix:

<table>
<thead>
<tr>
<th>Percentage of kWh Sold</th>
<th>Percentage of kWh Bought</th>
<th>Percentage of Households Cleared</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Total Energy Traded</em></td>
<td><em>Total Energy Traded</em></td>
<td><em>Total peers whose demand &amp; supply is met</em></td>
</tr>
<tr>
<td><em>Total Energy supplied for sales</em></td>
<td><em>Total Energy demanded for purchase</em></td>
<td><em>Total Number of peers</em></td>
</tr>
</tbody>
</table>

- **The percentage of kWh sold** assesses consumption of total supply from the sellers perspective.
- The higher the ratio, the higher sellers excess PV outputs.

- **The percentage of kWh bought** evaluates fulfillment of total demand from buyers perspective.
- The higher the ratio, the higher buyers demands are met.

- **The percentage of households cleared** quantifies fulfillment of the amount of buyer and seller contracts submitted at each hourly auction interval.
- The higher the ratio of household cleared, the higher the number if participants satisfied within the microgrid.
Prototype for Blockchain based P2P trading:

- Grid Connection
- Rooftop Solar
- Smart Contracts

Proof of Concept (PoC)

Simulink Model of 10 Households

5 Prosumers and 5 Consumers

1 Unit of Energy = 1 Token

Smart Meters measure the energy produced and consumed

Hyperledger Sawtooth 1.x – DLT Platform

Node-JS 8.x (web application back-end)

Python/ C/ C++ (Smart-Contracts)

Web Based Application for Prosumers, Consumers & DISCOMs
Policy Recommendations:-

- Regulations for P2P energy trading may be considered at CERC-level. UPERC had included P2P energy trading in their solar rooftop regulations, however, there is no clear indication for implementation.

- National-level technical standards for P2P energy trading platforms (including open-source) could be formulated, which comes under cyber security.

- Regulators may ask utilities to set up pilot projects based upon P2P trading.

- Changes may be required in the business model of utilities keeping P2P energy trading in-mind.
Future Work:-

1. The proof of Concept shall include group of households with different ratio of consumers and prosumers.

2. More distributed Energy resources such as Battery Energy Storage and Electric Vehicles shall also be included in the Proof of Concept (PoC)

3. Implementing Pilot Project (along-with a distribution utility) on the findings of Proof of concept.