Peer-to-Peer Optimal Solar Energy Trading using Proof-of-Authority Blockchain Technology

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***Abstract*—With Malaysia's growing populations and improved lifestyles, the demand for energy would only increase posing new challenges and problems to the energy sector. This project proposes a peer-to-peer web-based solar energy trading platform that is to be built utilizing Blockchain technology. The aim of this project is to optimize energy usage by homes, such that those that require higher amounts, can trade energy instead of paying higher energy bills. The back end of the platform is to be built using the Golang, while using the Angular framework for the front end. Energy forecasting and double auction mechanism is also included for optimal energy allocation and they are written in Python. Moreover, the platform utilizes the MongoDB NoSQL cloud database to securely and reliably store its data.**

***Index Terms*—Solar Energy, Blockchain, Double Auction, Energy Forecasting, Frontend and Backend**

I. Introduction

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II. Methods

A. Energy Forecasting

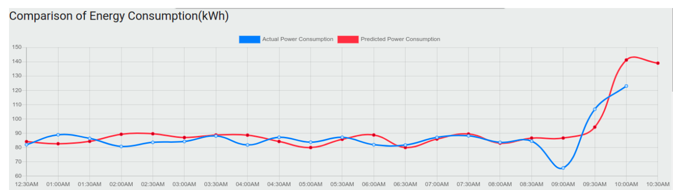


Fig:1 Prosumer specific energy consumption forecast vs time

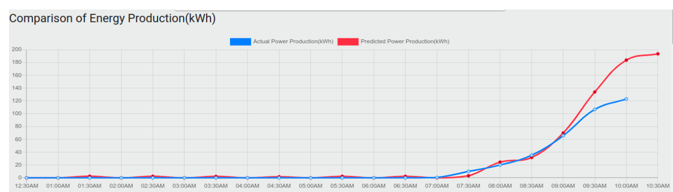


Fig:2 Prosumer specific energy production forecast vs time

1) Why Energy Forecasting: For our implemented web application, we are assuming that the solar energy a prosumer generates is stored in a battery and the energy balance is stored in a smart metre in their homes. Using this stream of data from the smart metre, we forecast the amount of energy consumed as well as produced for a given day. By predicting the energy consumption, we can limit the prosumer to a max energy value that they can make an order for. This ensures, that no prosumer orders extremely large energy amount that even the grid cannot produce. By predicting the energy production, we can limit the prosumer to a max energy value that they can use to make a bid on an energy request. This ensures, that no prosumer makes a bid that exceeds the max predicted amount they can produce.

2) How Energy Forecasting is done: The energy forecasting uses Triple Exponential Smoothing[4] with Additive Trend and Seasonality and relying on the latest two data pounts for seasonal period[5]. The training also includes Trend Damping to prevent the rise of unrealistic trends and thereby account for Seasonal Irregularity[5]. Once training is done using all the data points upto a certain time of the day a forecast is generated for the next 30 minutes from that point in time. This is the maximum energy forecast depending on what feature the prosumer is making use of. If the prosumer wants to make an order, they are shown their forecast graph for energy consumption. If the prosumer wants to make a bid on an energy request, they are shown their forecast graph for energy production.

B. Optimal Energy Allocation via Double Auction Mechanism

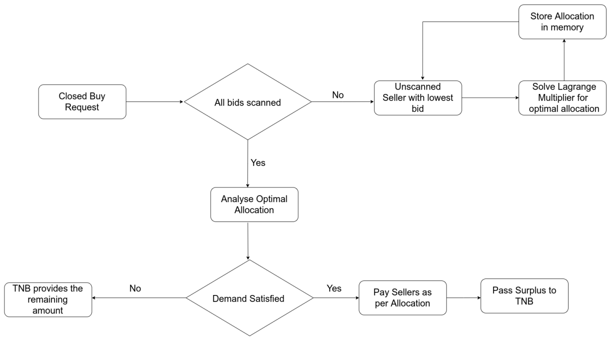


Fig:3 Flowchart for double auction with demand and supply response

1) Optimal Allocation Problem, OAP: The purpose of solving the OAP is to ensure that there is no one prosumer who can out bid everyone else, meaning all bidders are guaranteed to receive some compensation. Moreover TNB, as the main electricity providers in Malaysia, are also guaranteed to receive a reward since the system will use their grid lines to distribute the energy. The OAP is adapted to serve prosumer-to-prosumer energy allocation from one that uses Electric Vehicles and Service Providers[1]. It is defined in [1] as :

$$OAP : \max_{E^n, S^n} \sum_{i=1}^{I} \sum_{j=1}^{J} [b_{ij}^n \ln e_{ij}^n - p_{ji}^n s_{ji}^n] \tag{1}$$

where

E^n is the energy requested by the prosumer,
S^n is the energy that bidder can provide on the request,
I is the request made by the prosumer,
J is the total number of bids on the request,
b_{ij}^n is the price the bidder wants from the prosumer,
e_{ij}^n is the energy the prosumer can receive from the bidder,
p_{ji}^n is the price the prosumer is willing to pay to bidder,
s_{ji}^n is the energy the bidder can trade with the prosumer,

If we use the Langrangian method to solve the OAP for the local maximun[7] values for energy receivable by a buyer and energy tradable by a bidder, then we get the following:

$$e_{ij}^n = \frac{b_{ij}^n [(n \sum_{j=1}^{J} e_{ij}^n - e_i^{n,\min}) + 1]}{n w_i} \tag{2}$$

where
n is the battery charging efficiency,
w_i is the charging willingness,
$e_i^{n,\min}$ is the minimum energy the buyer needs,
and

$$s_{ji}^n = 2 c_1 s_{ji}^n + c_2 \tag{3}$$

where, $c_1 and c_2$ are cost factors for the bidder,

2) Why Double Auction: : The double auction mechanism solves the Optimal Allocation Problem (OAP) for distributing energy to each seller in a bid such that all sellers as well as TNB can receive some amount of the payment whilst fulfilling the energy request made by prosumer.

C. Blockchain

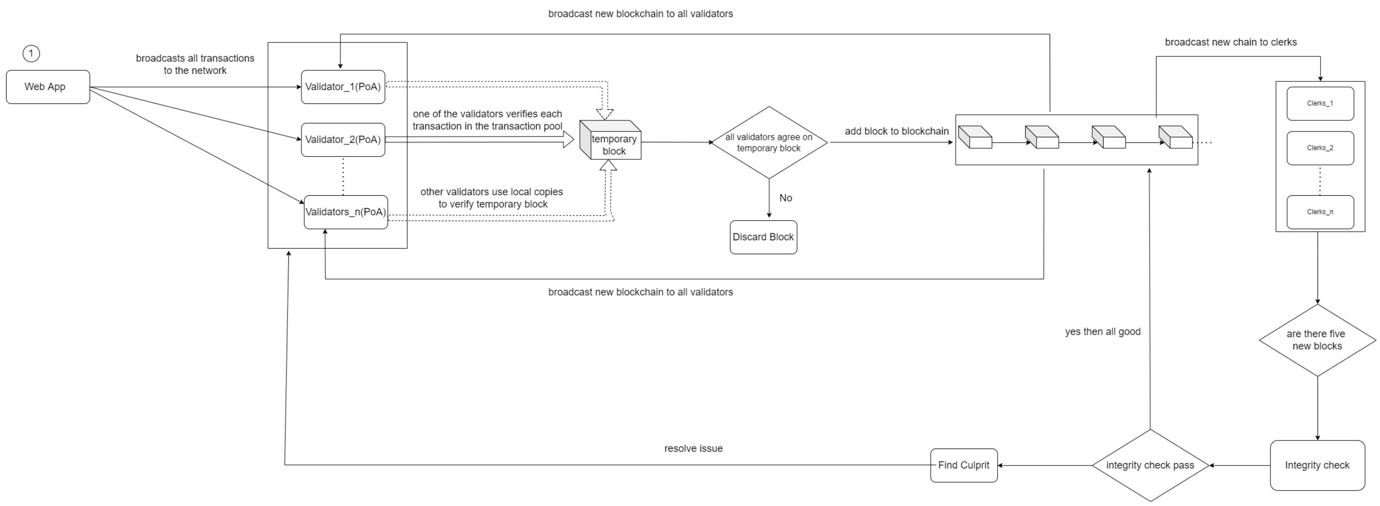
As shown in Fig.1, the blockchain uses a Proof of Authority(PoA) consensus mechanism where only validators are given the authority to mine new blocks and add new ones to the blockchain. We also have a new kind of users called clerks who are there for validator accountability checks. This is to ensure that validators do not conspire to work against public interest.

1) Roles in the Blockchain:

- *Validator*: A validator is one who has been granted the right to verify transactions, mine new blocks, add and discard blocks. Since we are using a Proof of Authority consensus mechanism, the validators undergo a rigorous registration process where they need to reveal their identities. Their reputation is at stake which means if they go against the interest of the normal nodes on the chain, then their status as validators will be revoked and made known to the greater community.
- *Clerk*: Clerks provide an additional layer of integrity check on the blockchain to ensure that validators do not conspire against the community. After the addition of every new block, they receive an updated local copy of the blockchain and user accounts. They will use their local copies to check whether the nonce of the last block from the central blockchain provides the same hash when they use it on the transactions in their local blockchain copy. If the match does not happen for more than 50% of the clerks, then an integrity check is triggered. Unlike validators, any normal node can be made a clerk and they do not need to be rigorously identified.

2) Blockchain pipeline:

- *Transaction Verification and Signing*: After the double auction is run every 30 minutes, the new pool of transactions are broadcasted over the network to all the validators. The validator who receives the transaction pool first, will verify each transaction where they check whether the buyer has sufficient balance or not. If so, then that transaction is marked as verified and made part of a temporary block. If a buyer does not have the required balance then the transaction is marked invalid. Once all the transactions have been checked, and added to the temporary block, it is then broadcasted to all the remaining validators. These validators use their local copy of user accounts to verify each transaction in the temporary block. They then use the nonce of the temporary block to hash the transactions from the latest block in their local blockchain. If this hash matches with that of the temporary block for all validators then the temporary one is made permanent and added to the central blockchain.
- *Discarding Blocks*: If there is a validator who does not find a match for the hash, then their local copies of user accounts and blockchain is updated. Then the check is done again. If the hash fails to match a second time, then that block is discarded. The non-match signifies that a transaction was manipulated in the central blockchain and so the block discarding is justified.



- *Integrity Check*: After the formation of 5 new blocks, an accountability check is triggered where the clerks verify each transaction in the latest permanent block in the central blockchain. They use their local copy of user accounts to verify each transaction in the latest block, then use the nonce of the latest block to hash the transactions from the latest block in their local blockchain. If the hash matches that in the central blockchain for more than 50 percent of the clerks, then there is no issue but if the match is less than 50 percent, then an integrity check is issued. This goes the through the local blockchain copy of each validator and compares the hash of the latest block. The validator(s) whose hash has a mismatch is then flagged. In this case the validator access may be revoked. This guarantees that validators do not work against public interest.

References

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