Energy Blockchain - An energy trading platform using Blockchain Technology

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***Abstract*—The blockchain is a non tamperable ledger built on top of distributed network and enables the transactions to be secure and transparent. This research paper will emphasize on peer-to-peer energy trading using Blockchain technology and Smart Contracts. It helps prosumers to sell an extra amount of energy as well as consume energy according to their demand without depending on intermediates. Peer-to-peer trading helps in eradication of brokers. The Ethereum Blockchain helps in rapid deployment, easy payment settlement, and transactions. We have proposed Powerloan system - a credit based payment system. Energy coins will be provided to users based on their credit value. Stackelberg Game is used to maximize the utility of a credit bank.**

Index Terms - Blockchain, Decentralized ledger, peer-to-peer, Energy trading Stackelberg game, Ethereum blockchain

I. INTRODUCTION

Today, Blockchain technology seems to be one of the hottest and widespread technologies. It seems to serve all the intents and purposes to be among the biggest tendencies of the contemporary world. Day by day, this technology is gaining a lot of popularity. In this field, we propose a novel application of Blockchain technology in a completely decentralized peer to peer energy trading platform [20], without concentrating the control or power to any centralized authority. The blockchain application resides on thousands of computers, all over the world and is maintained and taken care by a combination of common people and computer experts, collectively known as miners. It takes place via peer-to-peer interested individuals, with no intermediary bank or individual to take a slice and thereby eliminating mediator. NRGcoin - A new currency based on Bitcoin rules was proposed for renewable energy trading [5]. In our model, all transactions are processed using smart contracts and prosumers follow a common algorithm while exchanging energies through different costing strategies [17].

There are numerous advantages and benefits of decentralized blockchain:
Fraudulence avoidance: Blockchain comprises of open-sourced ledgers, with every single transaction getting recorded on them thereby making fraud detection quite an easy process.The incorruptibility of blockchain systems is supervised and maintained by miners who do the task of validating transactions regularly. It is not linked to an individual's bank account or cash funds and is rather transferred onscreen in real time and securely with the blockchain recording all transactions [7]. Our blockchain deals with buildings having solar panels which store the solar energy and act as energy nodes in which there is sufficient amount of location energy nodes and exchange of energy among various nodes by a peer-to-peer manner.
Increased monetary proficiency: Decentralized ledger blockchain eliminates the requirement of any mediator and allows transactions to be made directly from person to person [13]. This assuages people's reliance on energy sources and other energy pools and dramatically improves financial efficiency.
Can be accumulated, not detached: Within the blockchain database, data can be inserted but never removed. Once data is stored in the blockchain, then records are permanently stored in the chained database. If nodes trade energy among themselves, changes in the blockdata are stored permanently and updates are made in the blockchain.
Sync automatically, not backup: Blockchain database is automatically synchronized via a peer-to-peer network. It means millions of backups exist globally so we dont need to have any backup for ourselves.

II. PROPOSED METHODOLOGY

The proposed platform is built on Ethereum blockchain.The smart contract is designed to record transactions from energy sources(producers) and choices from users (consumers). Each producer has its own Ethereum address; users interact with the contract using the owner's address by delegating their interaction to the Owner. The ethereum address that deploys contract becomes energy node and energy is initialized via mining. There are producers which demand energy. It is assured that each producer securely holds one own address and shares this address (a hash of the public key) with the Owner. The owner then calls a function, register the producer and allows its entry in the network, allowing it to call another function to record offers of energy. Although this peer-to-peer energy trading scenario is trending there are some common security challenges too. These are most insecure in large scale energy trading in the general market. In such a peer-to-peer model, there is an Powerhouse(stock of energy) to look after the continuous flow of transactions [9]. This paper exploits blockchain technology to design secure Peer-to-peer energy trading platform. Its application is further extended and more focused on other energies too like wind energy, electric energy.This paper deals with these points and contributes in the same manner.

1) Basic energy blockchain: There are buyers and sellers which trade among themselves according to their requirements and needs.

2) Powerloan System: In order to get rid of limitation of transaction confirmation delays, and explained a Energy bank-based payment scheme to support trading of energy and ensuring fast payment.

3) Ideal-Loan pricing strategy: Explaining mathematical terms used in Stackelberg game algorithm for Energy bank-based loans to optimize the the utility of the Energy bank (Powerhouse) and make it more efficient and effective.

Terms	Description
Energy Nodes	Energy nodes in the network
Powerhouse	Energy nodes derive initial energy to enter in the network from powerhouse
Seller	A node which has surplus energy
Buyer	A node which has deficient energy
Address Pool	Contains addresses of various nodes present in the network
Seller Pool	Contains addresses of potential seller nodes
Energy Coins	The proposed currency for energy trading

TABLE I
SOME TERMINOLOGY

III. BLOCKCHAIN-EMPOWERED ENERGY TRADING

A. *Components and Structure of Basic Energy Trading Platform*

All the P2P energy trading in present times takes place to balance energy supply and demand. The whole framework of energy trading consist of the following common terminology:

1) Energy nodes: A node can take up the role of buyer or a seller according to surplus or deficient energy it has in its account. A node that can neither be a buyer or a seller because it doesn't fulfill the threshold criteria acts as an idle node.

2) Energy Aggregators: The work of an energy aggregator is that of a broker or a mediator between a buyer and a seller node. It helps in setting up a communication between two parties who want to trade energy. Therefore an aggregator acts as a third party between the nodes.We propose a better method. The supposed work to be done by an energy aggregator(broker) here is managed by a smart contract which will ensure there is no involvement of a third party. The buyer and the seller interact directly without the presence of a broker.

3) Smart meters: The amount of energy that is traded and the respective price between the two nodes is according to the value calculated by the smart meter placed between any two nodes which deal in energy. Smart meters will incorporate the proposed pricing algorithm by taking in the account details such as energy already present in account, account address, surplus/deficient energy amount of the two nodes which are dealing/trading energy.

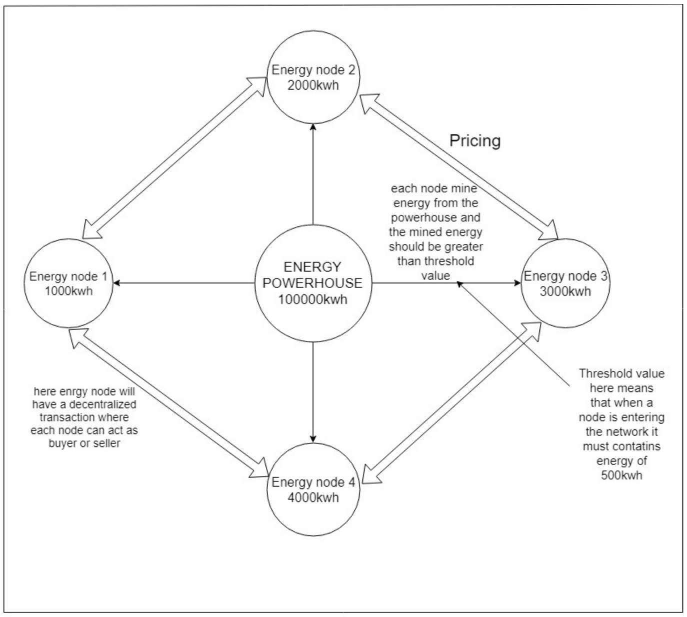
B. *Working of Secure Basic P2P Energy Trading*

In this day and age where vitality advancements and battery stockpiling frameworks are quickly improving, and the sharing economy is by all accounts disturbing each industry, numerous shoppers are asking, for what reason wouldn't we be able to exchange vitality? Shared (P2P) vitality exchanging hopes to address only that question by empowering individuals to purchase and pitch vitality to one another straightforwardly [6]. The following key points leads to better understanding of the energy blockchain with the help of of energy aggregators.

1) *System Framework and Entry of nodes in a network:* Firstly we register on Government authority, each node after registration becomes a different entity node. Each node j with a unique ID, gets its public and private keys. Each node obtains a set of wallet addresses and government authority initiates a mapping list and stores all the information in the memory pool. Wallet addresses basically contains energy coins and memory pool is an entity that stores all the transaction record of local energy nodes. There is a energy powerhouse which is a source of large amount of energy. Every node requests a minimum threshold amount of energy from energy powerhouse in order to enter in a network at a cost of certain energy coins(ether). This will act as a checkpoint so as to ensure that only a limited number of nodes enter the network and the network is not flooded by infinite number of unreliable nodes. Therefore this will ensure much more security of the energy trading network. Fig. 1. shows how threshold acts in a network.

2) *Different Roles in Energy Network:* There are many nodes in network which act as either a buyer node, seller node or both. This is decided according to their energy storage (energy coins). There is a different fixed threshold value according to which decision is made. If a node has energy greater than or equal to the threshold value it is capable of being a buyer as well as a seller [12]. Otherwise, the node can only act as a buyer as this indicates that it does not have surplus energy that could be provided to another node for trading purposes. Therefore, such a node can act only as a buyer and not as a seller.

3) *Exchange of energy between buyers and sellers:* Aggregators(SC) works as a controller and keep the count of energy demand from local energy seller and buyer. So these energy aggregators work as broker and like a normal broker motivates more to invest. Smart contract's exchange function is responsible for all these transactions. It takes few parameters like address of buyer who wants to buy energy and amount of energy it wants to buy. The controller or smart contract matches buyer's requirements with any seller present



NETWORK OF OUR ENERGY NODES

Fig. 1.

in seller pool and having sufficient amount of energy to sell as per buyer's demand.The Buyer node has to pay some amount to seller node in the form of energy coins(ether) in order to earn some profit. This is how exchange of energy takes place.

4) *Payment Security plus Incentives and Rewards:* The energy nodes after exchanging energies obtain the updated blockchain data of new seller addresses and Energy coins. Each transaction needs to be verified digitally with digital signature of seller. Energy sellers verify this block chain data sent by aggregator and then validate it digitally. Incentives are also given to both seller and buyer in order to encourage more sharing of energy via our model or network, after this energy coins(ether) are increased on both sides i.e. buyer and seller, by some amount(incentive amount). Further rewards are provided to those nodes who exchange most frequently and are most active in terms of their contribution level.

5) *Hashing in Energy Blockchain:* For verification, each block carries a hash which is cryptographic to the previous blocks in the blockchain. Aggregator computes the hash estimation of its block dependent on an arbitrary value ϕ, timestamp, the previous block hash value, transactions etc., (denoted as previous data) Namely, Hash(ϕ + previous data) $<$ Difficulty. Here, Difficulty can be balanced by the framework to control the speed of discovering the particular ϕ. After getting a valid proof-of-work (i.e., ϕ), the quicker miner communicates the blocks and broadcast ϕ to other aggregator.

6) *Agreement Process for more security:* The agreement process is done by some authorized aggregators and a member(leader) who is the fastest aggregator. These members must have a valid proof of audited work. The leader communicates block information, timestamp, and its evidence of-work to other approved leaders for confirmation [15]. For direct review aggregators, assess the refreshed blockchain information and they confirm these block information by sending advanced marks to one another. Aggregator at that point sends this information to the leader. The leader dissect the received answers from aggregators. In the event that every one of the aggregators concede to the block information,records will be sent by the leader which includes current assessed block information and a comparing mark to every single approved aggregator for capacity, this square is put away in the refreshed blockchain [14].

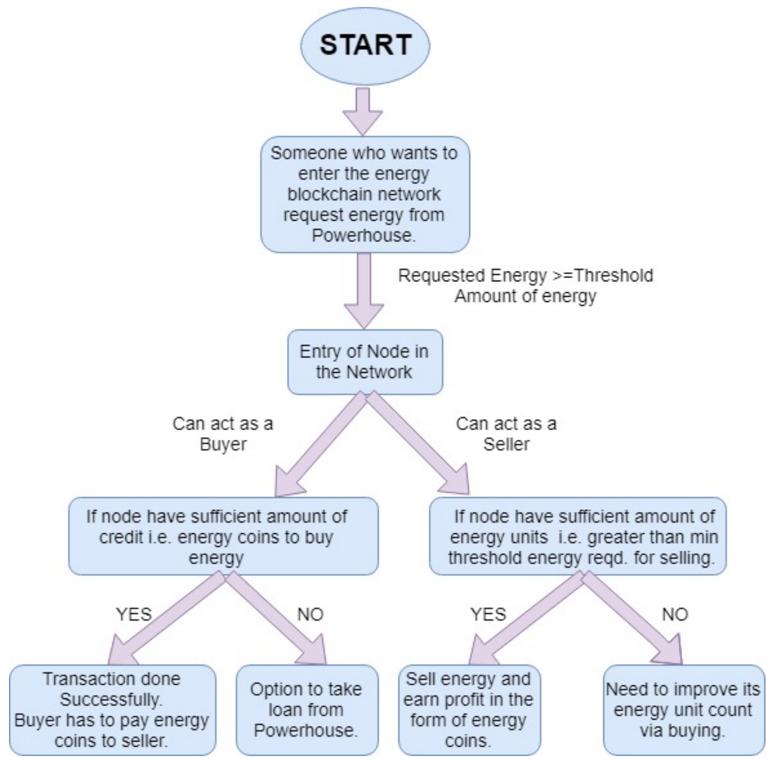


Fig. 2. Flowchart

IV. POWERLOAN SYSTEM

Sometimes the energy blockchain becomes idle and inactive due to lack of credit's status of buyers and sellers nodes. In order to make the blockchain work properly and continuously, this model has a separate body i.e. Powerhouse which solves this insufficient balance problem. Powerhouse acts as an powerhouse and provides energy coins to the Borrowers(person who wishes to take loan) which makes them capable of exchanging energy with other nodes of the network[2]. Each node has access to this powerhouse bank with enough energy. Sharing of energy between prosumers node and powerhouse is done which basically depends on the present balance of node and its previous background of transactions. On demand of energy nodes, energy coins will be exchanged from powerhouse energy stock to energy node's wallet address. There are the following operations energy node need to follow in the same sequential manner and represented in Fig. 3. too in order to get a loan from the powerhouse.

1) Loan Request Message: Initially a Borrower L_i (a Borrower energy node *i* is in need of energy coins) sends a request to the powerhouse and waits for an acknowledgment from the powerhouse in the form of a "Loan Request Success" message to finish its pending transactions.

Step 1 : L_i sends a request message along with other information like its own account address ID_i, all previously used transaction history $H_{i,k}{}_{k=1}^{K}$, loan amount energy $amount_i$ and current credit status $credit_i$ to the powerhouse P_m.

$L_i \rightarrow$P$_m$: $request_i$ = ID_i $\|$H$_{i,k}{}_{k=1}^{K}$ $\|$amount$_i$ $\|$credit$_i$

Step 2 : After powerhouse gets the $request_i$ from Borrower, it verifies the Borrower's identity, go through its previous transaction history from $H_{i,k}{}_{k=1}^{K}$ in account and seller pools both and check whether Borrower's account is active or not. At last, also calculates current status/balance of L_i from $credit_i$.

Step 3 : "Loan Request Success" message is obtained only to those Borrower's L_i who are able to fulfill certain following necessary requirements:

a) there is sufficient amount of $credit_i$ which must be positive amount.

b) the account must be active and should have at least 7-8 transactions in a recent time period.

Step 4 : A shared wallet SW_{pl}^{i} is created between powerhouse and Borrower. The public and private keys are sent to Borrower L_i. The powerhouse and Borrower both have access to use energy coins from the shared wallet SW_{pl}^{i} as per their need.

Step 5 : If all the requirements are fulfilled from Borrower's side, then L_i receives a "Loan Request Success" message M_i along with message signature M_{Sign} as a reply from powerhouse which indicates that the Borrower is eligible for Loan.

$P_m \rightarrow$L$_i$: $response_i$ = SW_{pl} $\|$M$_i$ $\|$M$_{Sign}$ $\|$ $Timestamp$

$where,$

M$_i$ = $amount_i$ $\|$status$_i$ $\|$t$_{repay}$ $\|$PR$_i$

Here, M_i includes some information like amount $amount_i$, current wallet status $status_i$, Repay time duration t_{repay} in which Borrower has to repay the loan otherwise has to pay late fee fine, and previous records of loans PR_i.

2) Completing Pending Payments : L_i finishes the payments using the obtained energy coins of wallet SW_{pl} . All payments made by the SW_{pl} wallet will get verified and as well as recorded at the same time by powerhouse. The powerhouse also puts the value of hash of data related to payments in PR_i. Following steps further elaborate the procedure:

Step 1 : L_i, the Borrower sends the given Payment along with the loan request success message M_i, message signature M_{Sign} to Seller. S_j verifies the certi as well as validates the duration of the wallet used for payment SW_{pl}. It also check the previous loan-based records of payments in energy blockchain to check the valid amount of energy in the wallet SW_{pl}.

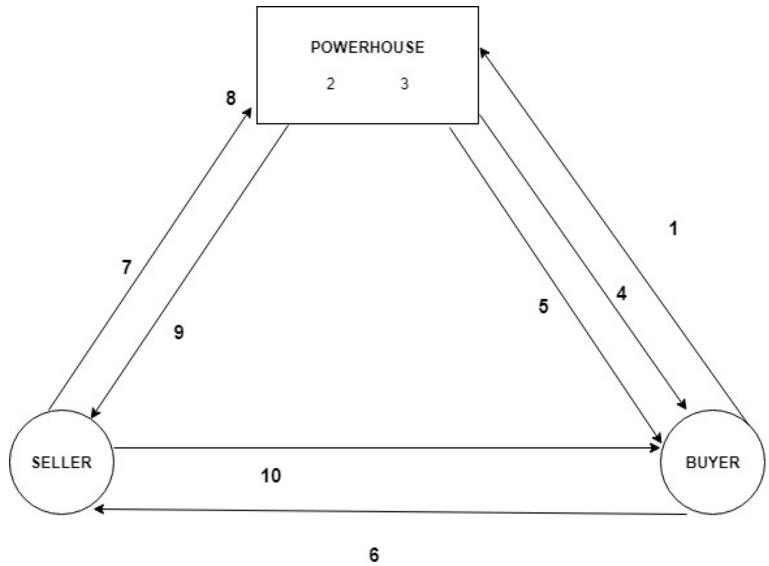


Fig. 3.

Steps	Working
1	Loan Request Message
2	Verification and checking of Previous Records
3	Checking necessary requirements
4	Setting up shared wallet and exchange of its information.
5	Acknowledgment message along with signature from Powerhouse authority
6	For more transaction send success message M_i to Seller node
7	More secured verification of success message and its contents.
8	Comparison of original message at powerhouse and received message from buyer
9	Transferring of energy coins in case of sufficient funds.
10	Energy is shared between seller and buyer and blockchain is updated with new information

TABLE II
10 STEPS PROCESS FOR POWERLOAN SYSTEM

Step 2 : S_j sends information attached with digital sign of this trade to the powerhouse such as the bill, the loan request success message M_i, address of wallet which is to receive the energy coins.

*Step 3 :*The powerhouse will compare the received success message M_i with the original success message in its record for verification via decryption technique. The Powerhouse then checks the status $status_i$ of this M_i, if it has sufficient funds then required energy coins are transferred to the wallet SW_{pl} to finish payment but if it is not the case, a message is sent to L_i stating "Not enough funds".

*Step 4 :*Now powerhouse updates the fund information of wallet SW_{pl} and message M_i along with adding a digital signature into the new message M_i^{new}. Therefore the processed payment procedure record is further inspected and inserted in the energy blockchain and simultaneously the new message is sent to the buyer for updation.

3) Repayment of Loan : After the duration of validity of M_i, L_i is encountered with new message M_i^{new} with information such as hash values of all the loan-based records of payments using M_i. The following possibilities are there:
1)*First possibility :* If the borrower L_i repays its loan within repayment-time then L_i is charged with a certain amount of interest along with the principle amount.

2)*Second possibility :* If L_i is not able to repay the powerhouse loan then one will be added to t_{repay} and credit-status of buyer will further degrade. The new credit-status value for the buyer will be updated as : $credit_{n+1}^{i}$ = $credit_n^i$ - q * $amount_i$. Where $credit_n^i$ denotes nth transaction's value of credit and q is a constant and q>0. Powerhouse will generate a transaction record about this process and it will get recorded into the address pool and inserted into the blockchain. So, even if the purchaser finally finishes paying the loan, L_i still experiences penalty on the loan amount.

3)*Third Possibility :* In case L_i is not able to repay the powerhouse loan for a considerably long period such twelve to eighteen months then the powerhouse will put this borrower into the blacklist which will ensure that no entity in the future cooperates with this entity by broadcasting this information to every node in the blockchain.

V. Ideal Loan Pricing in PowerLoan System

In this portion, we have examined that how the powerhouse and the borrower will expand their productivity by settling on an ideal measure of rate of interest and penalty and amount of loan individually [3]. Energy purchasers with insufficient Energy coins act as borrowers to apply for some amount of loan from the powerhouse. Borrowers likewise need to boost their profitability by asking the appropriate loan amount [11]. Starting now and into the foreseeable future, the borrowers filled in as Energy buyers are now eligible to buy energy from energy sellers.

A. Problem Detailing

In Powerhouse P_m, for a Borrower L_i, the loan amount given by a powerhouse $P_m(i.e.,\text{EB}_m)$ is denoted as A_i . The minimum energy resource demand for L_i is denoted as Q_i^{min}, and p_i is a given cost of the Energy asset before request of loan [5]. The fulfillment capacity of L_i is indicated as:

$$u_{\mathrm{f}} = d_i \ln\left(\frac{A_i}{p_i} - Q_i^{\min} + \phi_i\right) \tag{1}$$

where d_i >0 and ϕ_i>0 are the factors predefined for L_i. The utility of L_i is defined as:

$$u_i = \sigma_i\left[u_{\mathrm{f}} - y_i A_i t_i\right] - (1-\sigma_i)\, x_i A_i \tag{2}$$

where σ_i is repayment capacity of a loan, in particular, the likelihood L_i can reimburse the loan inside its repayment time. Records of previous loans comprises of a loan repayment record denoted by RP_i(s, f), where s denotes the number of loan repayed successfully within repayment time and f is the number of failures in repaying loan. We can calculate σ_i with the help of loan repayment record RP_i(s, f) of L_i. Here, $0 < \sigma_i = \frac{s}{s+f} \leq 1$.$y_i$ is interest rate of the loan controlled by the powerhouse. x_i is penalty rate i.e late fee given by the borrower in case of delay in repayment. We contemplate that the correlation between the rate of interest and the rate of penalty is x_i = $\eta_i t_i y_i$. Here η_i >1 is a predefined factor
The reward of the powerhouse comprises of the loan enthusiasm from L_i, and penalty if L_i can't reimburse the loan in time. The overhead of powerhouse is $A_i t_i c_i$. Here c_i is unit cost of L_i's loan for the powerhouse. Accordingly, the monetary advantages of the powerhouse are characterized as pursues:

$$u_{\mathrm{bc}}^{i} = z_i\left(y_i A_i t_i - A_i t_i c_i\right) + (1-y_i)\, x_i A_i \tag{3}$$

where z_i is predefined credit grade factor relied upon L_i's credit grade which is given by the powerhouse (here, $0 < z_i \leq 1$).z_i is determined from the loan narratives of borrowers. The credit grade of energy purchasers are arranged into various dimensions as indicated by credit estimations of energy purchasers. Higher credit grade brings higher z_i.
Behaviour or action of one entity affects decision of other as both powerhouse and the borrower wants to maximize their economic benefits and profitability respectively. To the degree that the financial segment is concerned, we think about two unique kinds of banking conduct: a Cournot game where the banks settle on their choice on the amounts of loans and stores at the same time i.e. they make their output decisions simultaneously, and a Stackelberg model in which they act sequentially.
A Stackelberg game formally tells us about the staggered basic leadership procedures of various independent decision-makers (i.e.,followers) in light of the choice taken by the main player (leader) of the stackelberg game. We at that point determine the Stackelberg balance of the planned game [8].
In this paper, powerhouse is the leader and borrower is the follower. The leader sets its decision(penalty rate x_i) for every borrower, separately. Follower observes the decision of the leader and reacts with the best outcome of loan(i.e A_i) as per the penalty rate given by powerhouse. The game G is formally

characterized by its key structure as:

$$\mathbb{G}=\left\{\left(\mathbb{L}\cup\left\{\mathbf{P}_m\right\}\right),\left\{u_i\right\}_{i\in\mathbf{I}},\left\{u_{bc}^i\right\}_{i\in\mathbb{I}},A_i,x_i\right\} \tag{4}$$

The target functions for the powerhouse i.e the leader and a borrower i.e. the follower in the powerhouse are, respectively,denoted as follows:

$$\begin{array}{c}\text{Leader: } \max_{x_i}\sum_{i=1}^{\mathrm{I}}u_{\mathrm{bc}}^i\left(x_i\right)\\ \text{s.t. } x_i\geq 0\\ \text{Follower: } \max_{A_i}u_i\left(A_i\right)\\ \text{s.t., } A_i>Q_i^{\min}p_i-\phi_ip_i\end{array} \tag{5}$$

B. Problem Solution

Backward induction methodology is used to get the Stackelberg Equilibrium for the game defined above. We first equate L_i's favourable amount of loan (i.e.,A_i), and penalty rate are determined by the powerhouse.

By differentiating u_i defined in (2) with respect to A_i,we have

$$\frac{\partial u_i}{\partial A_i}=\frac{\sigma_id_i}{A_i-Q_i^{\min}p_i+\phi_ip_i}-\sigma_iy_it_i-\left(1-\sigma_i\right)x_i \tag{6}$$

$$\frac{\partial^2u_i}{\partial A_i^2}=-\frac{\sigma_id_i}{\left(A_i-Q_i^{\min}p_i+\phi_ip_i\right)^2}<0 \tag{7}$$

As the second derivative of u_i is negative we'll obtain a strictly concave function. We acquire the optimal methodology by solving

$$\frac{\partial u_i}{\partial A_i}=0 \tag{8}$$

as follows:

$$A_i^*=\frac{\sigma_id_i}{\sigma_iy_it_i+\left(1-\sigma_i\right)x_i}+k_i \tag{9}$$

where $\mathrm{k}_i=Q_i^{\min}p_i-\phi_ip_i$

$We substitute (9) into (3), then$

$$u_{bc}^i=\frac{\sigma_id_i\left[z_iy_it_i-z_it_ic_i+\left(1-z_i\right)x_i\right]}{\sigma_iy_it_i+\left(1-\sigma_i\right)x_i}+k_i\left[z_iy_it_i-z_it_ic_i+\left(1-z_i\right)x_i\right] \tag{10}$$

We simplify the above equation as follows:

$$u_{\mathrm{bc}}^i=\frac{r_1^by_i-r_2^b+r_3^bx_i}{\sigma_iy_it_i+\left(1-\sigma_i\right)x_i}+r_4^by_i-r_5^b+r_6^bx_i \tag{11}$$

Where $r_1^b=\sigma_id_iz_it_i, r_2^b=\sigma_id_iz_it_ic_i, r_3^b=\sigma_id_i\left(1-z_i\right)$, $r_4^b=k_iz_it_i, r_5^b=k_iz_it_ic_i, r_6^b=k_i\left(1-z_i\right)$
By differentiating u_{bc}^i with respect to x_i,we have

$$\frac{\partial^2u_{\mathrm{bc}}^i}{\partial x_i^2}=-\frac{2r_2^b\eta_i}{\left(\sigma_i+\eta_i-\sigma_i\eta_i\right)x_i^3}<0 \tag{12}$$

$\mathrm{k}_i<0$, we have $\lim_{x_i\to 0}u_{\mathrm{bc}}^i=-\infty$ and $\lim_{x_i\to+\infty}u_{\mathrm{bc}}^i=-\infty$. When $k_i<0$, for $0_i<\sqrt{-\frac{r_2^b\eta_i^2t_i}{\left(r_4^b+r_6^\eta t_it_i\right)\left(\sigma_i+\eta_i-\sigma_i\eta_i\right)}}x_i>\sqrt{-\frac{r_4^b\eta_i^2t_i}{\left(r_4^b+r_6^b\eta_it_i\right.}}\left(\sigma_i+\eta_i-\sigma_i\eta_i\right)$, we have $\frac{\partial u_{\mathrm{bc}}^i}{\partial x_i}<0$, respectively.(13)

The utility function u_{bc}^i initially increases, and then decrease with increasing x_i.The function is a convex function. There exists a maximum value. So we obtain the ideal pricing loan strategy by

$$\frac{\partial u_{\mathrm{c}}^i}{\partial x_i}=0 \tag{14}$$

$$x_i^*=\sqrt{-\frac{r_2^b\eta_i^2t_i}{\left(r_4^b+r_6^b\eta_it_i\right)\left(\sigma_i+\eta_i-\sigma_i\eta_i\right)}} \tag{15}$$

When $k_i>0$,$x_i<0$. Therefore, we have $x_i^*=0$. For simplicity, optimal strategy of the powerhouse can be rewritten as:

$$x_i^*=\begin{cases}0,k_i>0\\ \min\left(\sqrt{-\frac{r_2^b\eta_i^2t_i}{\left(r_4^b+r_6^b\eta_it_i\right.}}\left(\sigma_i+\eta_i-\sigma_i\eta_i\right),x_i^{\max}\right),k_i\leq 0\end{cases} \tag{16}$$

$$y_i^*=\frac{x_i^*}{\eta_it_i} \tag{17}$$

Algorithm 1 Ideal Loan Pricing Algorithm

Initialize u_c^{i*} = 0, u_i^*= 0,A_i^*= 0,x_i^* = 0
for The interest rate x_i from 0 to x_{max}^i **do**
for Each borrower i $\in\mathbb{I}$**do**
if k$_i$ >0 then
A_i = 0, x_i = 0
break
end if
Borrower i adjusts its loan amount A_i according to
$\mathrm{A}_i^*=\frac{\sigma_id_i}{\sigma_iy_it_i+(1-\sigma_i)x_i}+k_i$
The bank manages its utility according to $u_{\mathrm{bc}}^{i*}=z_i\left(y_i\right.$ $\left.A_it_i-A_it_ic_i\right)+\left(1-z_i\right)x_iA_i$
if$\mathrm{u}_c^i\leq\mathrm{u}_c^{i*}$ then break
end if
end for
The SE(A_i,x_i) is achieved [19].

So as to accomplish Stackelberg balance (SE), the powerhouse needs to communicate with every borrower [1]. Algorithm 1 is introduced to give a distributed path to all the borrowers and the powerhouse so as to obtain the unique Stackelberg equilibrium iteratively, of the suggested game.

VI. RESULTS

Theorem :A unique Stackelberg Equilibrium can always be accomplished between the borrowers and powerhouse in the proposed Stackelberg game G.
Proof: As $\frac{\partial u_i}{\partial A_i}<0$, this signifies that the second derivative of

the utility function given in equation (2) is less than zero, it can be said that utility function has a maxima and it is strictly concave in nature with respect to A_i [18]. For any penalty rate $x_i>0$, a unique A_i is determined by each borrower such that the utility function u_i is maximized. Clearly, the game G achieves the SE when the powerhouse and all the borrowers(i.e., players) accomplish their advanced utilities, individually, reviewing the strategy that the players have used. Hence, it can be stated that as soon as the powerhouse formulates an ideal price x_i^* along with the borrowers choosing an ideal amount of loan A_i, Stackelberg Equilibrium is achieved. Since, it can be further noted from equation (12) that the function u_{bc}^i is strictly convex with respect to x_i. Therefore, it is clear that according to strategies of the borrowers, the powerhouse can determine a unique and optimal price x_i^*. Fig. 4 demonstrates the way in which the economic benefits of powerhouse and ideal loan amount of the borrower converges. Also, it can be noted that as soon as the ideal loan amount and economic advantages values are in vicinity of their optimal values, they converge rapidly. Therefore, a unique SE exists.

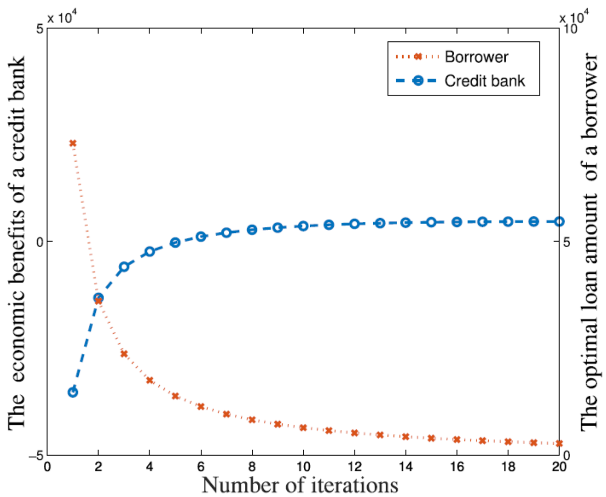


Fig. 4. Optimal solution graph for bank and borrowers[1]

VII. CONCLUSION

Through this paper, we have proposed an energy trading platform using blockchain technology in order to provide continuous supply of energy by more secure and convenient methods.The use of smart contract has directly and automatically controlled the energy flow and currency flow. This research paper emphasizes on peer-to-peer energy trading using Blockchain technology and Smart Contracts[16]. The Ethereum Blockchain helps in rapid deployment, easy payment settlement, and transactions. By using Blockchain Technology, prosumers are free from depending on any central body and provides advantages of the decentralized model. Now, prosumers can either buy or sell energy as per their demand without relying on any intermediate. Our model has a powerhouse which is a stock of both energy units and currency i.e. energy coins. We have also proposed a Powerloan System which acts as a bank from where the buyer can take a loan in case of insufficient balance and complete its pending transactions. This makes our model more faster and overcomes transaction limitation issues as now more transactions may occur. Powerloan system is explained with proper security analysis on both sides of powerhouse(bank) and borrower.For ideal pricing of both powerhouse(interest and penalties) and borrowers(buyers who take the loan), we have explained the mathematical approach of Stackelberg game for maximizing their respective economic profits. It chooses an optimal value for both amount of loan to be taken and the respective interest rate to be applied by the powerhouse. Both of these factors are in turn dependent on each other.

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