Storage as Decentralized Automated Market Maker

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***Abstract*— Operating rules are necessary for building a decentralized automated market maker (D-AMM) for energy storage, in order to incentivize energy storage holders to participate and ensure the success of the market. The D-AMM has been successfully applied to the cryptocurrency exchange market, where users have shifted from centralized exchanges to decentralized markets for greater trading profits. The operating rules of D-AMM are integrated into decentralized market operations and have become a successful market maker. Research has found that these rules revolve around setting transaction prices, liquidity pool, and pricing algorithm, and include a reward system that incentivizes traders and increases user volume. This paper proposes operating rules for the D-AMM in energy storage, which customize the incentive mechanism of setting transaction prices and formulate a pricing algorithm that encourages user participation, ultimately creating a win-win solution for users to generate surplus profits and a successful D-AMM market for energy storage. (*Abstract*)**

Keywords—D-AMM, transaction prices, liquidity pool, pricing algorithm, incentivize, reward system, user volume, win-win solution, surplus profits, blockchain technology

I. Introduction

Decentralized automated market makers (D-AMMs) have been successfully applied to the cryptocurrency exchange market to incentivize users and increase trading volume [3]. D-AMMs use algorithms to set transaction prices and manage liquidity pools, allowing users to trade without the need for a centralized exchange. Two protocols including Uniswap and Curve are mainly used in the algorithm of D-AMM to: 1.) non-custodial trading, 2.) provide liquidity for trading 3.) charge low fees for trading [1][2][3]. The success of D-AMMs in the cryptocurrency market has sparked interest in the application of this technology to the energy storage market.

Most importantly, the application of D-AMMs to the energy storage market has the potential to revolutionize the way energy is traded and consumed. By incentivizing energy storage holders to participate in trading, D-AMMs can increase the efficiency of energy storage systems and minimize cost of electricity bill for participants. D-AMM creates a level playing field for energy storage providers, and create incentive for providers to purchase new energy storages so that to meet the high demand for excess energy and continue making more surplus of profits.

To create the above system environment, the operating rules for D-AMM will be key to the successful implementation of a decentralized energy storage market and the rules give a win-win solution for all stakeholders. We have researched multiple sources of academic journal and conference papers narrating the success of D-AMM in cryptocurrency market using blockchain technology, and how its incentive mechanism can be used to create a similar one: "D-AMM for energy storages". The operating rules for D-AMM must take into account various factors, such as setting transaction fees, managing liquidity pools, and designing pricing algorithms. The pricing algorithm is especially important as it determines the price of excess energy that providers want to sell, and the transaction fee associated with the amount traded. In this study, we propose a dynamic fee structure for transaction fees that aligns with offering bonuses or other incentives to energy storage providers who meet certain performance benchmarks. This operating rule will answer two fundamental questions: 1.) how to set transaction fees and 2.) what the general pricing algorithm should include to incentivize energy storage owners to participate.

To accomplish this, we will formulate a numerical model to quantify the idea and develop an optimization problem to determine its results. Our objective is to implement this operating rule carrying a dynamic fee structure in the D-AMM for energy storage. This approach will create a win-win situation for both the market maker and energy storage providers by providing a surplus in profits in this new decentralized trading market. By designing an operating rule that takes into account the dynamic nature of transaction fees and provides incentives for energy storage providers to participate, we can increase the efficiency of energy storage systems and reduce the cost of electricity for consumers.

II. Research

A. *Decentralized Exchange*

In the paper "A Comprehensive Study of Decentralized Exchanges," Gompf, Qin, and Berg-Saether analyze the current landscape of decentralized exchanges (DEXs) and provide insights into the benefits and limitations of these platforms. They highlight the growing popularity of DEXs and note that these platforms offer several advantages over traditional centralized exchanges, including increased security, transparency, and accessibility.

The paper also discusses various types of DEXs, including order book-based, automated market maker-based, and hybrid models. Specifically, it mentions Uniswap and Curve as two prominent examples of AMM-based DEXs.

Regarding the creation of a decentralized automated market maker for energy storages, the insights provided in this paper can be helpful in designing a platform that is secure, transparent, and accessible to all users. The AMM-based model used in Uniswap and Curve can be applied to the energy storage market, allowing users to trade energy directly with each other without intermediaries.

However, there are several challenges that need to be addressed, such as ensuring fairness in the trading process, preventing market manipulation, and establishing rules and regulations that ensure a level playing field for all market participants. Additionally, it is important to consider the unique characteristics of the energy storage market, such as the variability of energy supply and demand, and the need for real-time balancing of energy flows.

Overall, the insights provided in the paper inform the possibility of utilizing the technology to design a decentralized automated market maker for energy storages, and can help ensure an accessible platform that is secure, and transparent to perform transaction and activities of trading among energy storage providers.

B. Setting Transaction Fee and Incentives

In the paper "An Incentive Mechanism Design for Microgrid Based on Blockchain Technology" by K. Wang et al. (2019), the authors present an incentive mechanism design for microgrids that uses blockchain technology [7]. The paper proposes a dynamic fee structure and reward system to encourage optimal performance and incentivize the adoption of new energy storage units. In addition, we found a research topic by C. Shi et al. (2019) that discussed how blockchain-based microgrid systems can reduce transaction costs and maximize economic benefits for all stakeholders [6]. Another notable source was a paper by J. W. Contreras et al. (2021), which provided valuable insights into how transaction fees and incentives can be leveraged to promote optimal performance and maintain a level playing field [4].

C. Users

Our primary understanding is that energy storage providers will only enter the market if the surplus they generate covers their electricity costs or provides additional profits. Additionally, our secondary understanding is that market participants who struggle to keep up with market demands may be encouraged to purchase new energy storage units to remain competitive and generate profits. The market maker's incentives will incentivize providers to make such purchases, with the return on investment being visible over time.

III. OPERATING RULES

We propose a comprehensive set of operating rules essential for the successful operation and optimal performance of a decentralized automated market maker for energy storage. These include a dynamic fee structure for transaction fees, performance-based rewards for marketing incentives, and an incentive structure for purchasing new energy storage units.

A. Dynamic Fee Structure

A transaction fee can be implemented using dynamic fee structure by the market maker and is inclusive in the pricing algorithm [6]. The dynamic fee structure can be determined such as:

$$\Phi_B + (T * \Pi) = \Phi \tag{1}$$

where:

Φ_B *:* A *fixed base fee* that is charged for each transaction [\$/kWh]

T *:* The *total Volume* of energy being traded [kWh]

Π: A *variable rate* that is adjusted based on the current trading volume [%]

Example:

If the base fee is $0.10/kWh per transaction and the fee rate is 0.1% of the transaction volume, then the fee for a transaction of 100 kWh would be:

*Fee = 0.10 [$/kWh] *100 [kWh] + (100 *0.1 [%]) = $0.20;*

B. Performance-based Rewards

The reward system can be justified by the system of Performance-based rewards. Performance rewards will be issued in the form of incentive to energy storage providers who meet certain performance benchmarks. This can be based on their ability to meet demand or efficiency of their energy storages. The performance-based rewards can be determined such as:

$$Reward = Base\ Reward + (Perf.\ Score * Perf.\ Rate) \tag{2}$$

Base Reward: A fixed reward that is given to energy storage providers who meet certain performance benchmarks. [$/kWh]

Perf. Score : A measure of provider's performance, such as efficiency of their storage units or their ability to meet demand. [/100]

Perf. Rate: A *variable rate* that is adjusted based on the current performance score [%]

Example:

If the base reward is $100 and the performance rate is 0.5% of the performance score, then a provider who achieves a performance score of 90 out of 100 would receive a reward of:

*Reward = 100[$] + (90 * 0.5 [%]) = $145.00;*

C. Incentives for Purchasing New Energy Storage Units

The incentive to purchase new storage can arise from increased and consistent volume over a period of time, given that discharging, charging loss, and storage efficiency will decay in existing storage due to overwhelming volume of trade. However, providers are uninformed and sensitive about the time taken to see their return of investment. The incentive to purchase new energy storage units can be created by offering incentives to energy storage providers who are meeting performance benchmark and unable to keep up with the demands of the market, such that they are incentivized to purchase new energy storage units in order to maintain their competitiveness and continue to generate profits. The incentive can be priced such as:

$$Incentive = Base\ Inc. + (New\ unit\ cost * Inc.\ Rate) \quad (3)$$

Base incentive: a fixed incentive given to providers who purchase new energy storage units [$]
New unit cost: the cost of the new energy storage unit [$]
Incentive rate: a variable rate that is adjusted based on the cost of the new unit [%]

Example:

If the base incentive is $500 and the incentive rate is 10% of the new unit cost, then a provider who purchases a new energy storage unit for $10,000 would receive an incentive of:

$$Incentive = 500\ [\$] + (10{,}000\ [\$] * 10\ [\%]) = \$1{,}500;$$

IV. Application

A. Requirements of Energy Storage Participants

Energy storage owners will be incentivized to participate in the decentralized market if the potential profits they can earn from trading energy are greater than or at least equal to the costs associated with maintaining and operating their energy storage systems, including their electricity bills.

Therefore, a dynamic fee structure that adjusts transaction fees based on the current trading volume and demand for energy storage, as well as performance-based rewards and incentives, can help ensure that energy storage owners are able to participate in the decentralized market and generate profits.

By offering bonuses or other incentives to providers who meet certain performance benchmarks, energy storage owners are more likely to maintain a high level of performance and upgrade their energy storage systems to ensure optimal performance. This will help to ensure that energy storage providers are able to meet the demands of the market and maintain their competitive advantage, while also contributing to a more stable and efficient energy market overall.

B. D-AMM System Environment Proposal

- A decentralized automated energy storage market maker implements a dynamic fee structure that adjusts transaction fees based on the current trading volume and demand for energy storage in the decentralized market. During peak hours when energy prices are high and demand for energy storage is high, the platform increases transaction fees to encourage energy storage providers to maintain their storage units and ensure optimal performance.
- In addition to the dynamic fee structure, the market maker itself offers performance-based rewards and incentives to energy storage providers who maintain a high level of performance and who are able to keep up with the demands of the market. For example, a provider that consistently sell its excess energy during peak hours receives bonuses and additional qualified incentives, in order to encourage the provider to maintain its energy storage systems and to create the incentive of upgrading them to increase the provider's storage capacity.
- Furthermore, the market maker could offer additional incentives for energy storage providers to purchase new energy storage units that are more efficient and able to handle larger trading volumes. An example would be the market maker offer subsidies or discounts to providers that purchased and installed new energy storage systems that meet the minimum performance criteria in order to participate in the decentralized market.

C. Dynamic Fee Structure

The platform charges a base transaction fee of $0.10 per kilowatt-hour (kWh) traded. In addition, this fee subjects to change based on the current trading volume and demand for energy storage. The fee structure could be defined in this way:

i. If the daily trading volume is less than 1000 kWh, the transaction base fee remains at $0.5/kWh and charges a fee rate of 2.5%.
ii. If the daily trading volume is between 1000 and 5000 kWh, the transaction fee increases to base fee of $0.10 per kWh and fee rate of 5%.
iii. If the daily trading volume is greater than 5000 kWh, the transaction fee increases to base fee of $0.15 per kWh and fee rate of 5%.

D. Performance-based Rewards

i. If an energy storage provider consistently sells at least 500 kWh during peak hours each day, they receive a bonus of $0.05 per kWh sold during those hours.

E. Application

- An energy storage provider has excess energy stored in their energy storage system and decides to participate in the decentralized energy trading platform.
- During peak hours, they sell 1000 kWh of energy at a price of $0.20 per kWh, generating $200 in revenue.
- The transaction fee for this trade is calculated based on the dynamic fee structure, which is currently charging base fee of $0.10 per kWh and fee rate of 5% for daily trading volumes between 1000 and 5000 kWh. Therefore, the total

transaction fee for this trade is $150 ($0.10 per kWh x 1000 kWh + 1000 kWh x 5%).

- Since the energy storage provider met the performance benchmark of selling at least 500 kWh during peak hours, it qualifies to receive performance-based rewards. Here, it receives a bonus of $0.05 per kWh sold during those hours. 1000 kWh of excess energy sold channels a total reward of $50.
- After deducting the transaction fee and including the performance-based bonus, the energy storage provider generates a profit of $100 from this trade.
- The energy storage provider could use this profit to offset their electricity bill.

If they consistently participate in the decentralized energy trading platform and generate profits, they may consider upgrading their energy storage system to increase their storage capacity and potentially generate even more profits in the future.

By offering bonuses or other incentives to providers who meet certain performance benchmarks, energy storage owners are more likely to maintain a high level of performance and upgrade their energy storage systems to ensure optimal performance. This will help to ensure that energy storage providers are able to meet the demands of the market and maintain their competitive advantage, while also contributing to a more stable and efficient energy market overall.

F. *Incentives for Purchasing New Energy Storage Units*

Let's assume that the cost of the new energy storage system is $5,000 and that it will increase the energy storage owner's capacity by 50%. The owner expects to generate an additional 500 kWh of excess energy during peak hours each month with the new system.

i. If an energy storage owner upgrades their system to increase their capacity by at least 50%, they are eligible for a one-time subsidy of $1,000 towards the cost of the upgrade.

ii. In addition, if the owner consistently generates at least 500 kWh of excess energy during peak hours each month with their upgraded system, they receive a monthly discount of 10% off the total transaction cost involving base fee and fee rate.

V. RESULTS

i. The energy storage owner decides to upgrade their system at a cost of $5,000, knowing that the increased capacity will allow them to generate an additional 500 kWh of excess energy during peak hours each month.
ii. Because the upgrade increases the owner's capacity by 50%, they are eligible for a one-time subsidy of $1,000 towards the cost of the upgrade.
iii. With the upgraded system, the owner consistently generates 500 kWh of excess energy during peak hours each month.
iv. Because the owner meets the performance benchmark of generating at least 500 kWh of excess energy during peak hours each month with their upgraded system, a monthly 10% discount is eligible and can be applied to their transaction fees.
v. If the energy trading platform charges a transaction fee with base fee of $0.10 per kWh and fee rate of 5%, the owner would normally pay $75 in transaction fees each month for their excess energy sales (500 kWh x $0.10 per kWh + 500 kWh x 5%). However, with the 10% discount, their transaction fees are reduced to $67.50 each month ($75 x 0.9).
vi. Over the course of a year, this discount amounts to $81 in savings on transaction fees ($7.50 per month x 12 months).
vii. When combined with the $1,000 subsidy towards the cost of the upgrade, the energy storage owner's net cost for the new system is reduced to $3,919 ($5,000 - $1,000 + $81).
viii. The energy storage owner can calculate how long it will take to recoup their investment in the upgraded system based on the additional revenue they expect to generate from selling the extra 500 kWh of excess energy each month. If they sell this energy at a price of $0.20 per kWh, they would generate an additional $100 in revenue each month. Therefore, it would take approximately 39 months to recoup the net cost of the upgrade ($3,919 / $100 per month). After this point, the energy storage owner would begin generating additional profits from their increased energy storage capacity.

VI. RECOMMENDATIONS

A new approach can be taken on researching and formulating an optimization problem for energy storage providers in the liquidity pool for energy storage. For the example above, we can aim to formulate an optimization problem to maximize the net profit of energy storage providers over a certain period of time. Few considerations based on example can include the energy storage capacity, the amount of excess energy generation, cost of buying electricity from utility, transaction fee setting. In the optimization, the objective function can be taking the revenue made from selling excess energy, and minus the cost of new energy storage, transaction fees, and utility cost. In this optimization, we can regulate the decentralized market by including the operating rule of every energy storage participants must maintain a minimum level of energy storage capacity in order to participate in trade, while ensuring fairness and preventing unfair practices.

In addition, this approach could be further enhanced by incorporating machine learning algorithms to forecast energy demand and supply, which would enable energy storage providers to make informed decisions about their energy storage capacities and potential revenue. Additionally, by integrating real-time data monitoring and automated decision-making, the optimization process can be streamlined and made more efficient. Furthermore, this approach could also explore the potential benefits of utilizing renewable energy sources, such as solar or wind power, to reduce the cost of electricity from utility companies and increase the revenue potential for energy storage providers. Ultimately, by taking a comprehensive approach that combines optimization techniques, machine learning, and renewable energy sources, we can create a decentralized market that is efficient, fair, and sustainable.

REFERENCES

[1] Hayden Adams. (2018). Uniswap Whitepaper.

[2] Dan Robinson. (2020). A Simple Explanation of Uniswap. Fabian Gompf, Kaihua Qin, and Bjarne Berg-Saether. (2021). A Comprehensive Study of Decentralized Exchanges. IEEE Access, 9, 33863-33881.

[3] J. W. Contreras, J. L. Rueda-Márquez, J. M. Gómez-Pulido, and F. J. Aguilar-Jiménez, "Blockchain and Smart Contracts for Energy Trading Systems: A Review of Applications, Architectures, and Challenges," Energies, vol. 14, no. 6, p. 1579, Mar. 2021.

[4] R. Rahimi, N. Koochakzadeh, A. Khalilian, and M. K. Makki, "A decentralized energy trading platform based on blockchain: Development and operation," Renewable Energy, vol. 153, pp. 838-850, May 2020.

[5] C. Shi, L. Su, X. Lin, Y. Yu, and Q. Zhang, "Optimizing transaction fees for energy trading in blockchain-based microgrid systems," Applied Energy, vol. 258, p. 114080, Dec. 2019.

[6] K. Wang, K. Chen, Y. Li, Z. Wang, and X. Ma, "Incentive Mechanism Design for Microgrid Based on Blockchain," in 2019 IEEE International Conference on Energy Internet (ICEI), May 2019, pp. 99-104.