Seeking a Solution to Ever-Evolving Energy Grids

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Abstract

The energy sector, a critical component of the United States' infrastructure, is at a crossroads due to evolving consumption trends and demand for renewable generation. This transformation brings to light the limitations of traditional, large-scale energy grids, which are vulnerable during critical moments, inefficient due to their centralized nature, and hurt energy producers and consumers alike. Originating from an effort during the Summer of 2021, where I conceptualized this idea, the initiative seeks to decentralize and democratize energy distribution within a community by providing a technical solution to enable efficient transactional energy capabilities. The project aims to tackle the inefficiencies and inequities of centralized energy distribution by developing a platform utilizing blockchain technology and smart contracts, enabling autonomous community management of energy resources and promotion of local generation — reducing costs and fostering equitable participation in an energy market. The goal of securing the Nachman Innovation Challenge grant is to further develop the concept into a scalable, real-world application, exploring opportunities to enhance sustainability and reduce dependency on legacy energy systems.

Proposal

Background

The problem with existing power distribution:
In our current system of transacting energy resources, both producers and consumers rely upon the same large-scale and utility owned energy grids. The infrastructure set by these parties is necessary for any and all power distribution, but can reveal its vulnerabilities during critical moments.[1] [2] Power is typically generated far away from where it is consumed, delivered by massive transmission systems which cover large geographical areas, creating risky points of failure which can blackout entire regions.[3] Despite the pitfalls of this system, it creates a lucrative structure for utility company whos transmission fees billed to consumers accounts for billions of dollars in ratepayer costs.[4]

Incumbent utility companies, backed by regulatory frameworks and legal monopolies, often resist transitioning to local renewable energy sources. Policies define markets, and utilities are very influential in policymaking, which means many existing policies are friendly to utility interests — and those are hard to change, because the utilities will fight hard to maintain policies that they like. Individuals with solar generation frequently encounter barriers preventing them from selling their energy at fair rates due to regulatory barriers,[5] hindering public equity and the adoption of sustainable energy alternatives.[6]

Smart contracts and blockchain:
Blockchain refers to a type of cloud-computing network which processes information flow, there exist various networks who each boast capabilities of transaction speed, uptime, privacy, parallel processing, and cost. Blockchain platforms often lack cross-compatibility, necessitating the selection of a single platform for implementation.

In a blockchain ecosystem, there are special programs called smart contracts that play a key role in network interaction. Smart contracts are contractual agreements written into code. The contracts contain predefined immutable conditions, and can execute programmatically when its terms are met, without need for intermediary parties.

In the context of energy distribution, smart contracts have the potential to establish rules and conditions for energy trading.[7] This research opportunity seeks whether we can use the blockchain model to create a more equitable system of energy generation and transaction.

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[1] (2006). The anatomy of a power grid blackout - Root causes and dynamics of recent major blackouts. IEEE Xplore
[2] (2019). California Wildfires: How PG&E Ignored Risks in Favor of Profits. The New York Times.
[3] (2022). Risks in the European Transmission System and a Novel Restoration Strategy for a Power System after a Major Blackout. MDPI.
[4] (2020, June). How Two Simple Fixes Can Fairly Compensate the True Value of DERs in California. T&D World.
[5] (2023, August). NEM 3.0 in California: What You Need to Know. EnergySage.
[6] (2022, December). This little-known bottleneck is blocking clean energy for millions. The Washington Post.
[7] (2021). IEEE Blockchain Transactive Energy (BCTE) Position Paper. IEEE.

Proposed Activity

The concept is a comprehensive platform for autonomous community power management, leveraging blockchain technology and smart contracts to streamline energy transaction and overcome the limitations of legacy energy grids. By embedding the operational parameters of an energy market within smart contracts, a target community would use this platform as a plug-and-play solution to foster power interaction among all contained entities. This system would subdue transmission costs by focusing on local-generated power, and aim to incentivize private generation by offering an open market to producers.

My goal in receiving the Nachman Innovation Challenge grant is to extend this concept into a tangible solution with real-world applicability. The developed solution should not only be capable of deployment but also incorporate realistic market mechanisms to ensure its effectiveness. Subsequently, I will develop a thesis to evaluate the effectiveness of this solution and its impact on energy management practices.

Project Technical Specification

The platform will derive its mechanics from established energy and resource markets. Producers share their energy capabilities with the network, showing availability for power provisioning. Agreements are established both in advance, in anticipation of demand, and on-demand, to accommodate dynamic consumption needs.

Consumers will share their power needs with the network, and based on the established day-ahead preparation and on-demand provisioning delegation, power will be provided to the grid for consumption. The blockchain will serve as an immutable accounting ledger, ensuring wholly transparent and verifiable recording of transactions.

Addressing this proposal extends beyond software development, however. Movement of electrons necessitates a physical distribution infrastructure. A target community might need to establish its own power grid system, overseen and managed by a designated manager. Whether this responsibility falls on the developer, a homeowners' association (HOA), or another committed entity is of secondary importance. What matters most is a dedicated commitment to maintaining the requisite infrastructure for energy distribution within the community.

Furthermore, the project will likely introduce the concept of a community grid-service aggregator. This entity will play a crucial role in facilitating market-making activities for the entire local area, ensuring effective energy transactions and optimizing resource allocation within the community grid. The community grid aggregator will also oversee the management of energy storage systems and coordinate grid balancing activities to maintain stability and reliability within the network.

Research Questions:

The project aims to address specific vulnerabilities of the legacy energy grids, such as resilience against grid outages and distribution efficiency. The research questions are:

1. How can community energy platforms mitigate the inherent vulnerabilities of traditional grid systems?

2. What are the key components necessary for developing a realistic and deployable community energy platform?

3. What is the feasibility and impact of implementing blockchain-enabled autonomous energy distribution systems?

Research Objectives:

The objectives of this research project are as follows:

- <u>Develop a functional blockchain energy trading platform:</u>
  Leverage blockchain technology and smart contracts to establish a functional energy transaction system, facilitating independent energy resource management within private energy distribution areas.

- <u>Implement realistic market mechanisms:</u>
  Research and implement realistic market mechanisms that align with existing energy markets and regulations to ensure the platform's practicality and potential deployment within real settings.

- <u>Empower high-density small-scale providers:</u>
  Specifically focus on empowering high-density, small-scale energy providers, such as residential households, to actively participate in local energy generation and transactions.

Potential for Innovation

Advancement of the Field of Study

This project contributes to the energy sector by challenging and potentially reshaping the conventional paradigms of energy distribution and management. By using blockchain technology to facilitate energy transactions, we not only advance the theoretical framework surrounding transactive energy systems, but also provide a practical model for their implementation.

Advances in Technology

At the core of the project is the innovative use of blockchain technology to create a secure, transparent, and efficient platform for energy transactions. This project pushes boundaries of blockchain applications, moving beyond traditional financial uses to address real-world energy distribution challenges, demonstrating versatility and potential to revolutionize sectors of society.

Societal Relevance

The project directly addresses several pressing societal challenges, including the need for sustainable energy sources, the reduction of carbon emissions, and the improvement of energy access in remote or underserved communities. By facilitating the local production and distribution of renewable energy, the project promotes energy independence, reduces reliance on fossil fuels, and can contribute to more equitable energy access.

Alignment with Larger Efforts:

The proposed effort is a continuation of a project I worked on in Summer 2021. The project, dubbed EnergyChain, was conceptualized by me and a partner from the company ElectriqPower to address the *IEEE Blockchain Transactive Energy (BCTE) Initiative*.[8]

The project makes use of the emerging blockchain technology sector, and strives towards the broad societal goals of reducing dependence on centralized grids, fostering local energy generation, and promoting sustainability.

This space has opportunity for real-world adoption, and further grants offered from both IEEE and various blockchain providers, which I intend to pursue with a more established project.

[8] (2021). IEEE Blockchain Transactive Energy (BCTE) Position Paper. IEEE.

Timeline

(2-4wk) Research all requirements of system
- Review concepts from previous effort
- Think thoroughly of how the project would work in the real world
- Determine all necessary variables and components of an energy distribution market
- Select a blockchain platform
- Solidify technical specification

(1-3mo) Build out software components, work through unforeseen blocks
- Implement smart contracts reflective of accurate market mechanisms
- Establish methods for entities to participate in the market
- Create simulation environment
- Create visual interface

(1-4wk) Fine tuning of the platform
- Ensure realistic market mechanisms
- Seek further improvement of platform

(1-4wk) Testing and validation

(~) writeup

(~) Seek interested parties in deployment of the project

References

Fotis, G., Vita, V., & Maris, T. I. (2022). *Risks in the European Transmission System and a Novel Restoration Strategy for a Power System after a Major Blackout*. MDPI. https://doi.org/10.3390/app13010083

IEEE. (2021). *IEEE Blockchain Transactive Energy (BCTE) Position Paper*. https://blockchain.ieee.org/images/files/pdf/ieee-bcte-state-of-the-grid-position-paper_05-2021_final.pdf

Jian, W., Fu, B., & Wu, Z. (2022). *Blockchain-based smart microgrid power transaction model*. ScienceDirect. https://doi.org/10.1016/j.ifacol.2022.08.060

Lewis, C. (2020, June). *How Two Simple Fixes Can Fairly Compensate the True Value of DERs in California*. T&D World. https://www.tdworld.com/distributed-energy-resources/article/21132853/how-two-simple-fixes-can-fairly-compensate-the-true-value-of-ders-in-california

Obi, M., Slay, T., & Bass, R. (2020). *Distributed energy resource aggregation using customer-owned equipment: A review of literature and standards*. ScienceDirect. https://doi.org/10.1016/j.egyr.2020.08.035

Osaka, S. (2022, December). *This little-known bottleneck is blocking clean energy for millions*. The Washington Post. https://www.washingtonpost.com/climate-environment/2022/12/20/clean-energy-bottleneck-transmission-lines/

Penn, I., Eavis, P., & Glanz, J. (2019). *California Wildfires: How PG&E Ignored Risks in Favor of Profits (Published 2019)*. The New York Times. https://www.nytimes.com/interactive/2019/03/18/business/pge-california-wildfires.html

Pourbeik, P., Kundur, P. S., & Taylor, C. W. (2006). The anatomy of a power grid blackout - Root causes and dynamics of recent major blackouts. *IEEE Xplore*, *4*(5), 29. DOI: 10.1109/MPAE.2006.1687814. https://doi.org/10.1109/MPAE.2006.1687814

Thoubboron, K. (2023, August). *NEM 3.0 in California: What You Need to Know*. EnergySage. https://www.energysage.com/blog/net-metering-3-0/

Personal Statement

Hello.

My name is Tyler Lewis. I am a proud member of the Chapman EECS program. In my two decades I have observed rampant change in the world. Amongst fast-paced societal and technological growth, I have learned that change is inherent in our modern lives. Change holds the potential to continuously improve and revolutionize human civilization. Alas, growth is hindered by entities who do not prioritize change — they might even get left behind if they can't. Those motivated to embrace change for the betterment of society must adapt solutions to increasingly complicated problems.

I pursue this program, and subsequent research, because I am motivated to seek solutions to power a better world.

Requestor Name: Tyler Lewis	**Project Title: Seeking a Solution to Ever-Evolving Energy Grids**	**Totals**	Comments
Additional Student Name(s): ISO	**Project Start/Anticipated End Dates:**		
Personnel Costs:			
Salary Cost: (undergraduate or graduate students)	Name: Tyler L. Role: Lead	$ 8,550.00	
	Name: ISO Role: Co-lead/assist		
Personnel Subtotal:		*$ 8,350.00*	
Fringe benefit rate for student: 5%	0.05	$ 450.00	
Fringe Subtotal:		*$ 450.00*	
Other Direct Costs:			
Equipment costs (over $1K in costs and >1 year of life)			
Materials supplies	List items here: - blockchain tokens to facilitate testing of smart contracts	$ 200.00	Blockchain tokens used for running smart contracts
Travel (domestic travel)		$ 1,000.00	Potential domestic conferences - RE+ - ETH Denver Potential meetings regarding - Informational interviewing - Interest from an energy solution provider
Additional direct costs:	List items here:		
Other Direct Costs Subtotal:		$ 1,200.00	
REQUEST TOTAL:		**$ 10,000.00**	