An Intelligent Industrial Control System for Renewables and Micro-Grids operating on a Distributed Blockchain Network

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# Introduction

In recent years operational technologies have begun to adopt more modern software techniques to control industrial systems such as renewable energy sites, fossil plants, energy storage facilities. The advent of (IoT) internet of things, has propelled a new industry of devices focused on secure, reliable communications to be effective in residential settings but also in a harsh industrial environment. Industry 4.0 has been researched in the academic literature, and summarizes the growth of reliable cloud-hybrid solutions as well as more interconnected machine to machine communications known as Industrial Internet of Things. The dynamic landscape of energy generation has been shifting to ‘pro-sumers’ because of the exponential trends reducing costs of solar and energy storage. The requirements for generators has always been to manage large sites with dedicated resources but as technologies change the sites become more ‘hybrid’ with varying generation sources and storage solutions that are no longer solely controlled by utilities, and large companies. Micro-grids are still only used in small sectors based on demand of the region but the ability to abstract away generation using adaptive control systems has been researched by Oak-Ridge National Labs. They have developed open-sourced controllers that are capable of interfacing with various power electronics used by solar, wind and storage manufacturers. The modernization of these controllers are leading the way to adopting new types of protocols that build on cheaper, faster and more performant embedded systems. Another recent technology is the distributed ledger mechanism that also arises from performant hardware. It is more commonly known as blockchain. Platforms have arisen that allow the capabilities of smart contracts on these blockchains . Smart contracts resemble software logic and is used to essentially build distributed applications ono top of a blockchain network. The downside to blockchain systems have been the limited transactions per second , around 14, that keep these systems from scaling. They do however offer de-federation and security since all nodes must be in consensus when resolving the smart contracts. Recent literature has been able to show improvements of these blockchain transactions by utilizing deep-reinforcement learning techniques applied to nodes inside of an IoT network.

The goal of this paper is to combine the advances in blockchain transaction rates with industrial control system logic and simulate the results to see the capabilities of a such a system in a real-world environment performing tasks such as setpoint tracking, solar-smoothing, short-circuit impedance matching (more to be determined). The paper will cover the first step, retrofitting the open-sourced ‘SCIESMIC’ controller pioneered by Oak-Ridge National Labs to use a highspeed blockchain protocol. An overview of the enhanced blockchain with deep-reinforcement learning will be referenced. The next section will cover a simulation for a hybrid solar, wind and battery site. A traditional controller and a distributed controller will be simulated to perform setpoint tracking, and solar smoothing. Finally, the results of the controllers will be presented. A review of the response times and site efficiency will be provided.

# Dissertation Objective

The goal of this paper is to measure a distributed control systems performance using blockchain communication to secure and scalable critical infrastructure. The implementation of blockchains proof of work can improve security on a network, and smart contracts can enable immutable, and auditable control logic. The limits of blockchain technology applied to a simulated

# Literature Review

# In recent years operational technologies have begun to adopt more modern software techniques to control industrial systems such as renewable energy sites, fossil plants, energy storage facilities. The requirements for power companies has always been to manage large sites with dedicated resources but as technologies change the sites become more ‘hybrid’ with varying generation sources and storage solutions that are no longer solely controlled by utilities, and large companies. Industry 4.0 has been researched in the academic literature, and summarizes the growth of reliable cloud-hybrid solutions as well as more interconnected machine to machine communications known as Industrial Internet of Things. Micro-grids are still only used in small sectors based on demand of the region but the ability to abstract away generation using adaptive control systems has been researched by Oak-Ridge National Labs. Recent literature has been able to show improvements of these blockchain transactions by utilizing deep-reinforcement learning techniques, and Proof-Of-Authority applied to nodes inside of an IoT network. This paper strives to provide a measurements of a simulated controller operating across devices within a site.

# Approach

The theoretical approach is to implement Proof-O-Authority as a IoT blockchain transaction protocol. Use the communication on simulated power electronic devices emulating a site providing energy to a point of interconnect. Each simulated device will have a simulated controller implementing consensus based setpoint tracking by reading messages published by a meter device. Each device will also know the state of other generating assets allowing for theoretical simulations that require more complex control logic. Several approaches will be taken to ‘test’ the capabilities of a distributed system with a relatively slow protocol to operate a site with varying number of nodes over varying site conditions. A parametric result will be provided showing performance benchmarks as the system is scaled.

# Tasks to Be Completed

1. Generate a Benchmark :
2. Use default electrical simulations of wind/solar/battery sites using matlab and Simulink.
3. Run site output simulations using a real-world dispatch schedule (5-minute setpoints)
4. Capture data ( Faults, KW,VAR,Frequency, etc.)
5. Create a distributed network
   1. Build a simulated network of devices
   2. Each device will be either an ‘inverter’, ‘meter’,’breaker’, ’wind-turbine-controller’, or ‘operator’.
   3. Each device will be simulated using Matlab’s Simulink then compiled into executables that will run as virtual devices
      1. The devices would need to be benchmarked with real-world operations to validate the simulated responses
   4. Each device will have an instance of the distributed controller code interfacing with it to receive/send signals to other nodes on the network
   5. A Proof-Of-Authentication blockchain message will be published by nodes to the network allowing all other nodes to see the message and validate it as ‘real’, but only take action if its specifically for that node. (Creating a lot of chatter on network)
6. Test distributed network
   1. Track network packet size and rates from node to node and measure against existing bandwidth constraints at sites. Compare against 5G networks.
   2. Track response times to setpoint changes and stability of site with slow transaction rates, increase transaction rates to see what is needed for stable operations
   3. Increase node counts and understand bandwidth and performance limitations.

# Time Table

1. Research : 3/1/2020 – 5/1/2020
2. Finalize Approach : 5/1/2020 – 6/1/2020
3. Generate Benchmarks : 6/1/2020 – 10/1/2020
4. Create a Distributed Network Simulation : 10/1/2020 – 4/1/2021
5. Test Distributed Network : 4/1/2021 – 7/1/2021
6. Compile Results : 7/1/2021 – 10/1/2021
7. Publish Conclusion : 10/1/2021 – 11/1/2021

# References

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* A. Prajapati, R. Arno, N. Dowling and W. Moylan, "Enhancing Reliability of Power Systems through IIoT - Survey and Proposal," 2019 IEEE/IAS 55th Industrial and Commercial Power Systems Technical Conference (I&CPS), Calgary, AB, Canada, 2019, pp. 1-7.
* M. Liu, F. R. Yu, Y. Teng, V. C. M. Leung and M. Song, "Performance Optimization for Blockchain-Enabled Industrial Internet of Things (IIoT) Systems: A Deep Reinforcement Learning Approach," in IEEE Transactions on Industrial Informatics, vol. 15, no. 6, pp. 3559-3570, June 2019.

# Figures and Tables

 