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A Software Capable of Simulating Peer-to-Peer Energy Trading

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Abstract: Peer-to-peer energy trading is the idea that excess power generated by one end user would be sold to other end users hence compensating for the high cost of setting up a renewable energy system. The Agile Software Development Model with Extreme Programming Method will be used in this proposed peer-to-peer energy trading system. The recent invention of renewable energy systems has been game-changing. However, most of these systems are expensive to set up, localized, and mostly privately owned. Analysts believe that if these individual systems can have a shared pool/database where energy can be shared between end-users, we might have reached the Golden age of energy. Poor power supply has plagued many parts of the world. The major economic giants largely depend upon the steady electrical power supply. Many parts of the world utilize a conventional electric distribution system in which electricity is generated primarily from hydro dams and gas-powered power plants and distributed on a unidirectional path to end-users. Recently, there has been a fair acceptance of renewable energy systems. As per the industry stakeholders, renewable energy options can immensely contribute to the power system in any country. This research will look at the peer-to-peer energy trading system, requirements, architecture, ICT infrastructures, and the possibility of implementing such a system while using the existing Energy transmission system and distribution facilities. It aims to create software capable of simulating peer-to-peer energy trading software. It provides a web-based system with a user-friendly interface for accessing different system parts. This allows trading to be carried out effectively on the simulation. Users will be able to manage all trading using a single dashboard. This paper will also analyze a model of a peer-to-peer energy trading system.

Keywords: *Peer to Peer (P2P), conventional grid system, Wide Area Networks (WAN), Neighborhood Area Network (NAN), Home Area Network (HAN)*

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I. INTRODUCTION

Central power stations are the source of energy production, and the transformer enhances the voltage level, which is appropriate for the transmission. Then there is a need for voltage down to make electricity usable for the end-user. Many distribution companies are providing this kind of service. End-users get charged according to their electricity consumption through meter readings taken physically or sometimes using smart gadgets or smart meters [1, 2]. This method is effective for the small scale of the electric arraignment where electricity is generated in the small units [3]. Individual power generation and consumption are now a part of many countries' lifestyles. Many of the country's residents have come to accept that the body in charge of power generation, many distributing companies, cannot live up to its duties. This issue is further worsened by the frequent collapse of the national power grid that generates a meager 7000 megawatts from about 4800MW [4, 5]. Over 80% of the business depends on the steady electrical power supply, and one of the significant costs incurred by companies happens to be power generation. New options are frequently being tested, with many businesses looking to lower these costs to not burden the consumers [6, 7]. Many countries are now gradually accepting Renewable energy and power storage for further consumption [8]. This new set of prosumers (Producers-Consumers) who generate power for use happens to hold the key to solving the electricity power generation problem plaguing the country while reducing problems associated with global warming.

A. The Conventional Grid System

The conventional grid system currently being operated in many countries has been underutilized despite dams and other available energy sources that can be used for power generation. The grid system only allows energy to flow in one direction, i.e., from the producer to the consumer, and the lack of support for the Feed-in-Tariff (FiT) scheme further complicates any upgrade [9]. With the additional power of the primary grid, a scheme encourages this scenario called the FiT for the small-scale generators. The conventional grid still has its advantages. The system can be made effective and operated on a small scale at a large scale. "Large productive units can be optimized and operated with only a relatively small staff. The connecting network allows efficient energy usage and dispatch services at any time with the electric losses, which generates less energy [10]. The current distribution network can benefit the only one-directional flow of electricity, as discussed by [11]. As the population is going to be increase and the size and economy are also effective same with the retail electricity prices.

1) The traditional electricity system: In Traditional Electricity systems for the last 40 years, power sources are varied reported by System Operators, Hydraulic and Gas remain the primary sources, and electricity produced about 11.5-16Kv and stepped up by a step-up transformer 330kV. The voltage is further reduced to 0.415kV and continuously stepped down to 240V before getting to our homes or offices.

2) The electricity transmission and generating companies: The legacy system and regulatory commission charge the subsector that has 23 grid-connected that produce the plants in operations with a total installed capacity of 10,396 MW with a thermal-based generation having an available capacity of 8,457.6MW, and hydropower has the capacity of 1,938.4 MW of total available capacity with a capacity of 1,060 MW [12]. For example, "Transmission Company of Nigeria (TCN) manages the electricity transmission network in the country. It is one of the 18 companies that was unbundled from the defunct Power Holding Company of Nigeria (PHCN) in April 2004 and is a product of a merger of the transmission and system operations parts of PHCN."

3) The Distribution Companies (DisCos): The Distribution Companies supply power to the transformers in each locality. There are 11 Electric Power Distribution Companies in the country (whose distribution areas are differently colored. Each DisCo manages its locality and has different substations which help in monitoring power and distribution [13]. There are two types of distribution networks; one is a radial network, and another is a loop or network. This transmission network generally has two types, including radial and interconnected networks. An interconnected network has multiple connections to other points of supply.

B. Concept of Peer-to-Peer Energy Trading

Energy is the primary concern that grows exponentially as rapid-fire. While there is now a great range of increases in using this new energy source, the cost of setting it up is often high; it is not adequate. One of the lasting solutions to this growing concern is P2P energy trading. Peer-to-peer (P2P) energy trading is famous as a system that clicks consumers to become producers and distributors of electricity. The Peer-to-Peer system has been in existence for some time, with its popularity widely boosted by the emergence of Torrents. Peer to Peer energy selling is a rising domain that allows customers to trade amongst themselves [14]. P2P energy domain for business has the transparent business market the benefits of all the consumers and prosumers. To benefit from the local balance of consumption and power generation from new resources like renewable energy sources, thus becoming good at the power system is also necessary. With the expanding connection of renewable power origins, ancestral energy con- seasons are becoming prosumers, both utilizing and generating [15]. The primary energy trading among consumers and prosumers in a local power delivery system is called peer-to-peer energy selling, which was developed based on the "P2P economy" concept (also known as a yielding economy) [6]. The concept of peer in the P2P energy domain refers to one or a set of local energy customers, and it is included based on generators, end-users, and prosumers. The peers directly deal with each other for selling and buying purposes. In electricity, the transmission of electricity is opposite to the flow of the cash that the end-user paid for the usage of the consumed units—for example, Piclo in the UK, Vandebron in the Netherlands, and Sonnen Community in Germany. As a primary element of the P2P trial, energy providers provided incentive tariffs to customers. This research focuses on developing and implementing a Peer-to-Peer Energy trading platform with the two objectives. It investigates the Electricity market to see how it will be compatible with the Peer-to-Peer energy trading system and build a system that will simulate how Peer-to-Peer energy trading will work [10].

This model is available for Energy Sharing since peer-to-peer energy trading is an emerging market without fixed models. This model is usually compared with the conventional paradigm to point out its benefits to prosumers. In the old system, the suppliers buy the energy from the big giants at the wholesale price, and then they have a mechanism of selling to end-users. This makes a significant mark on this selling and buying convention from suppliers to end-users [11].

C. The Architecture of the Peer-to-Peer Energy Trading

According to the European Standardization Organizations [8], the proposed architect-natural model for Smart Grids needed to execute continuous standard improvement and development is the Smart Grid Architecture Model (SGAM). SGAM has a four-layer architectural system tailored for P2P energy trading. The four layers are further arranged in three dimensions for clarity.

1) First dimension: The first dimension organized the system to propose the best control system for layers arrangements. Dimension one arranges the system according to the needed layers for adequate control. These are the Power grid, ICT, Control, and Business layers.

This layer includes the distribution systems' transmission function and control systems like voltage control and frequency control [2].

2) Second dimension: This dimension organizes the system and includes the size of peers participating in energy trading. These peers include CELLS, the number of Microgrids, and the Energy Sharing Regions.

3) Third dimension: The last dimension shows the peer-to-peer energy trading process time sequence. This sequence includes bidding, which is always the first step here, followed by energy exchange, which occurs after an agreement between prosumers. The settlement is the last step, and it involves the payment of bills based on electricity consumed.

D. Peer to Peer Energy Trading in Traditional System and Electricity Distribution System

The distribution structure in the country measures the success of Peer-to-Peer energy. It will also rely on the available interconnected network, with the connection point of each network node being managed by an Energy Sharing Coordinator. The success of Peer-to-peer energy trading depends on the electric power distribution structures available in this country [10]. The availability of smart meters has already laid down the foundation for the system. A DisCo Substation will better manage a Peer-to-Peer Energy trading Cell.

E. Importance of Peer-to-Peer Energy Trading and Requirements

Some of the main advantages and requirements of P2P energy trading are that people make deals on their terms, and there are transparent dealings directly with other prosumers, which minimize operational costs [14]. According to facts and figures, the electricity distribution causes energy losses, and the more energy is transmitted, the more losses will occur. Therefore, it allows the consumers to buy electricity for personal use and deal with consumption according to their needs.

F. ICT Infrastructures for Peer-to-Peer Energy Trading

ICT has successfully penetrated different spheres of the world, and energy generation is not left out. ICT infrastructures are needed to implement a P2P energy trading system successfully. The infrastructures required for P2P energy trading include Smart grids, smart meters, and communication protocols.

II. REVIEW OF RELATED PAST WORK

Peer-to-peer energy trading has gathered enough attention to be put into trial by several people. Some of these trials and projects focused on different aspects of the system like ICT, business model, platform, etc. Here are a few of those projects:

A. Piclo (Electricity)

Piclo (previously known as Open Utility), owned by good energy, was launched in January 2013 with the mission to power the world with cheap, clean, and abundant electricity. Following a successful trial in Britain, the service was launched under electricity.

The other measure is the meter data, and the generator prices and consumer preferences according to the electric power demand and supply every half hour.

B. Vandebron

Vandebron is an online platform based in the Netherlands where electricity users buy electricity directly from independent prosumers, including farmers with wind turbines in their fields. Vandebron acts like a middleman linking consumers to the generator. Moreover, it also balances the whole market.

C. Peer Energy Cloud

Peer Energy Cloud is a research project developed by Germans. It works on cloud-based technology and for a local electronic trading platform for dealing with excessive local production [15]. It was designed to tackle new recording and weather procedures for device-specific electricity consumption, raise a virtual marketplace for power trading, and raise value-added services within a Microgrid [2].

D. Using Peer to Peer Energy Trading System Based on Vandebron Platform

The developed peer-to-peer Energy trading system will be based on the Vandebron online platform model. The Vandebron mode allows energy consumers to buy electricity directly from independent prosumers. Thus, their model will perfectly fit the developed peer-to-peer trading system [16]. The existing power generation capacity is inadequate and in need of fresh ideas. The availability of renewable energy is undoubtedly a huge step if it can be tapped to produce a peer-to-peer energy system [17]. Using the present energy transmission and distribution facilities on the ground would quicken the development of the system. The model of a Peer to peer energy trading system was discussed alongside some core ICT modules needed to set up the system. However, much attention was not given to the business model. We can fill this gap using this simulation software, which can be proved to be an emerging technology to uplift this particular domain in this area of power generation. Using the present energy transmission and distribution facilities on the ground would quicken the development of the system. The model of a Peer to peer energy trading system was discussed alongside some core ICT modules needed to set the design [18, 19]. However, much attention was not given to the business model.

III. METHODOLOGY AND TECHNICAL SPECIFICATIONS AND COMPONENTS DESIGN

There are various software development methodologies, each serving the same purpose with different approaches. Except for the data gathering aspects, this thesis used the Agile software development model for achieving its result.

A. The Agile Software Development Model with Extreme Programming Method

The agile software development model allows working software to be built in an iterative and fast process, noting that "This method is the more effective one to take care of the whole planning, managing, designing, coding, and testing the system. It is more convenient for development and less for the requirements [20]. PHP is a server-side encoded scripting language that builds dynamic web pages. PHP is a very powerful scripting language that can build traditional Websites and powerful web applications. HTML (Hypertext Markup Language) tags which are markups, tell a web browser how to display text, images, and other forms of multimedia on a webpage. CSS helps style the HTML pages. It deals mainly with the looks and presentation of HTML over a web browser. This application work on the Phalcon framework; it is a high-performance PHP framework based on the Model-View-Controller (MVC) architecture and implemented (ORM) in C with increased execution speed, asset management, and top security performance optimization [21]. Noted that Phalcon supports the two types of MVC frameworks: full-stack frameworks (like Symfony, Yii) and micro frameworks (like Lumen, Slim, Silex). The Phalcon PHP framework was chosen based on Web MVC Architecture, ORM, and Volt. The server used for this project is Apache HTTP. It is an open-source server available for modern technologies like operating systems UNIX and Windows. We need a stable server this can serve the best, and MYSQL will serve as the database.

B. Components Specifications

This section details the internal component of the system developed. Developing a peer-to-peer energy trading system entails a proper design of the overall system to cover every possible key feature needed for it to execute appropriately. The developed peer-to-peer trading system would have four components: Power Generation, Power Consumption, Power Storage, and Power Trading.

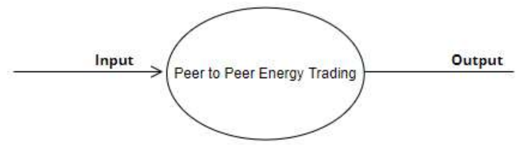

Fig. 1. Level 0 of the data flow diagram

C. The System Design

The diagram below (Fig. 2) shows how data flows into the system:

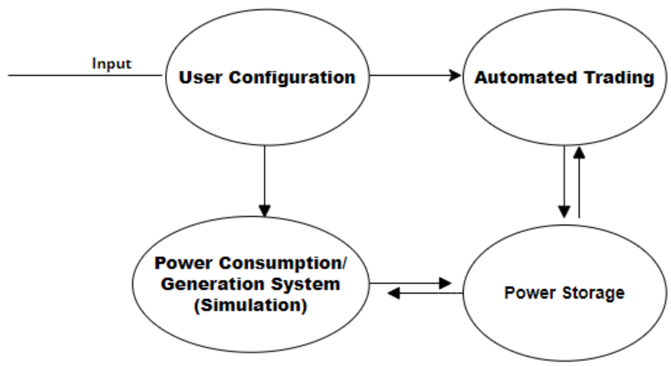

Fig. 2. Level 1 of the data flow diagram

The user gives input to the system, and the system processes it and generates output. Fig. 2 breaks the peer-to-peer energy trading into its sub-components. The users' input goes to the user configuration/preferences (storage settings, the power generation settings, the power-consuming settings, etc.). Fig. 3 gives a detailed view of how data flows within the system. Data flows into the power consumption simulator, which is being simulated from power consumption. If there is a power shortage based on the user's preferences, data flows back to the power utilization simulation, which can be seen in Fig. 4. Energy trading takes some power storage and takes the user's preferences to decide whether to trade or buy.

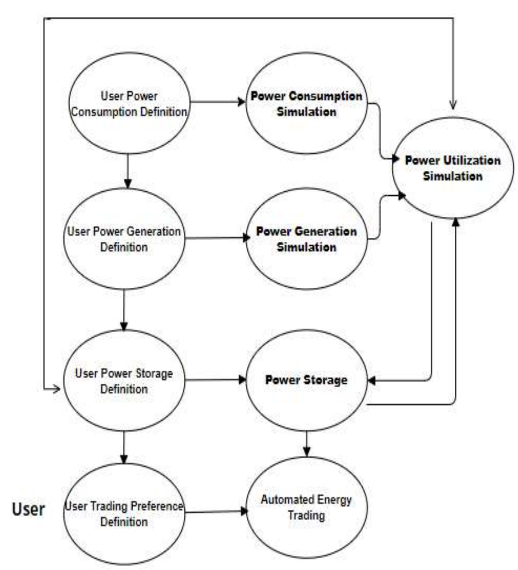

Fig. 3. Level 0 of the data flow diagram

Each of these classes will be translated to a table in the database that will store the information; Phalcon automatically generates the database from the classes via an object-relational mapper. This class represents a Prosumer's appliance. It contains information that will be recorded about the user's household appliances and what consumes the user's power. This class represents a Prosumer's battery pack. It has properties, including Current Capacity (the number of powers currently in the battery, it will determine if the battery is full or not) and Maximum Capacity (the number of batteries it can take). Every time the simulation usage runs, it will calculate the total usage of the person. The purpose of the system is to be recording the users' power usage over time. When someone buys energy, he spends money, and it will come from his wallet. It is a file that contains the transaction information; it will create a history of power transactions of a person. This is where the user's preferences will be stored, and several options will be set here. When someone buys energy, and once it is completed, the energy transaction file is what will hold the transaction. The primary model classes make up the application's domain logic.

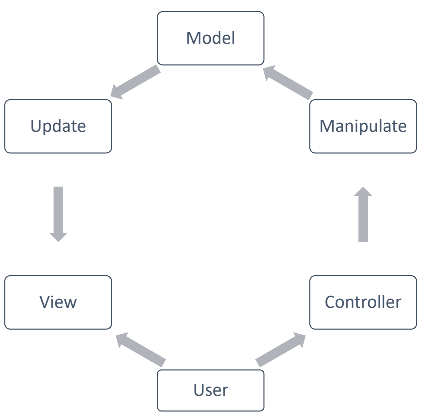

Fig. 4. A representation of the model-view-controller software design pattern

One of the best features of a web application is the ability to access its interfaces: Web pages (presented), Web Services, etc.) from any client (usually, but not always, a browser) over a network. The degree of accessibility could vary based on the scale of the network. The Internet is the largest of all, spanning multiple networks and locations. This means that billions of people could potentially access a web application hosted over the Internet globally within a second. However, this might be an exaggeration in practice due to various factors, the major one being the webserver.

IV. IMPLEMENTATION

The installation requirements for the software are essential. Locally, installing a WAMP or XAMMP server with an Apache server on a Windows P.C. will allow the software to run smoothly. Also needed is the Phalcon PHP extension - version: 3.4 with 64-bit architecture. Also, the software can be deployed online to any hosting company with a Linux server running Apache and has a Phalcon extension. Any code editor with support for PHP (syntax and code completion) is also required. Manual testing is carried out within the system to check for errors and ascertain trust.

The whole project is split into two parts. The web component presents an interface that allows an authorized user to manage their power infrastructure (appliance, generators, and batteries) and purchase/sell power from/to available traders. A new user would have to create an account to use the platform. All units were built separately and tested individually to ensure that they worked fine. This was done to ensure that ironing out bugs or carrying out future upgrades on a unit in the system will not bring the entire system offline. A functionality test is carried out to ascertain that all functions expected of the app are working without any problem. HTML, CSS, and BOOTSTRAP files were checked for any error loading files. The Phalcon libraries were checked too. Links between APIs are also checked to make sure they are not broken. Testing was first carried out from the localhost at 127.0.0.1; usability testing involves checking the user interface for friendliness and simplicity to promote the user experience. The dashboard was designed with bright colors and kept simple for easy navigation.

V. RESULTS

With the simulation engine running, the software's different modules were used, and the results were compiled. Fig. 5 below is a snapshot dashboard and its reports. The system also allows the users to show generators associated with the system and their information. In the simulation, these can be turned off and on from the dashboard. Fig. 6 shows a snapshot of generators. Amongst other parts of the system are the appliances module that allows connected appliances to be monitored in real-time and their consumption status noted. Fig. 7 shows a snapshot of the appliance. The simulation was executed three times with new users added and the overall system tested. The simulation engine handled all requests well, with the power generation and consumption being well noted. Also, trading was carried out effectively within the system, with all transactions being duly recorded. Users will be able to analyze the whole power trading at a single dashboard (My Appliances, My Generators, My Batteries, My Preferences, My Wallet, My Energy Traders).

Fig. 5. User dashboard

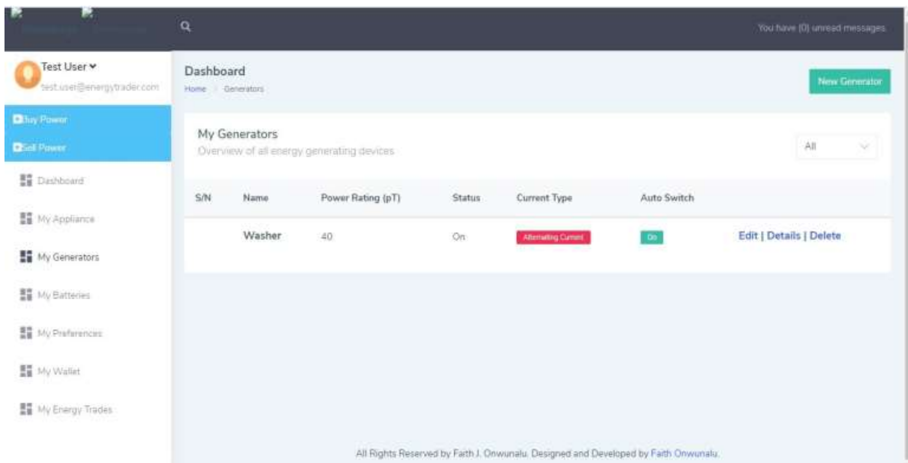

Fig. 6. Generators

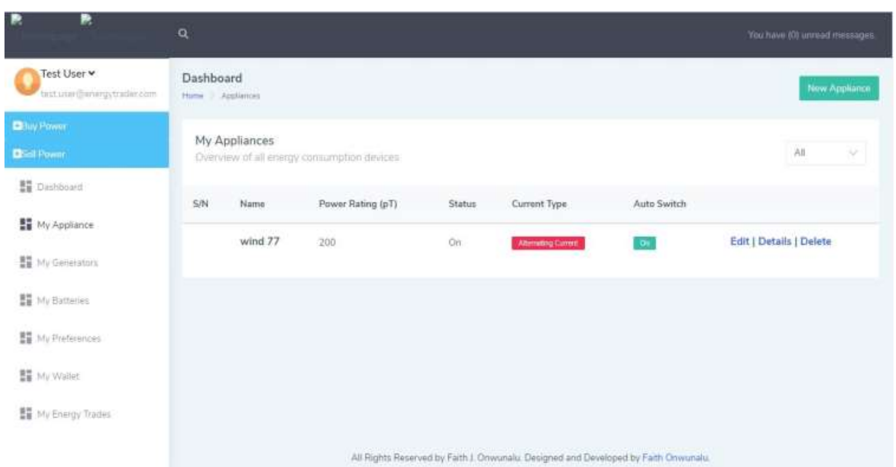

Fig. 7. Appliance

VI. CONCLUSION

This research is focused on investigating the possibility of setting up a peer-to-peer energy trading system to boost the power sector. The different aspects of a peer-to-peer energy trading a system was considered. Also, the existing infrastructures within the electricity sector were taken into consideration. A peer-to-peer energy trading simulator was built, and the trading operations were carried out. Our main aim is to create software capable of simulating peer-to-peer energy trading software. It provides a web-based system with a user-friendly interface for accessing different system parts. This allows trading to be carried out effectively on the simulation. The study concerns these individual systems that use a shared pool/database where energy can be shared between end-users; this might be considered the Golden age of energy as the end-user has the shared one-stop dashboard to manage all trading.

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