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Development of Communication Transaction Framework for Nigerian Electricity Distribution Companies

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Abstract: *Nigeria has been faced with incessant power outages as a result of poor communication between the country's electricity key players - Generation, Transmission, Distribution, System Operator, Regulatory Agency and Customers. This paper focuses on development of an appropriate communication framework for effective information flow between Distribution companies (DISCOs) and other directly linked actors in the wake of system deregulation and unbundling of the Nigerian electricity industry. DISCOs was selected because its critical role as the major and visible interface between the end users and other major sectors of the industry. In this work, a secured portal with requisite database that facilitated effective transaction and situational awareness in the Nigerian electricity industry has been developed. Functional network architecture was adopted in building up a communication network in a Mesh format to give multi-access link to operators. Adobe Dreamweaver was adopted as design tool, PHP Hypertext Preprocessor as scripting language and MYSQL for database management. The portal built was encrypted to ensure system security. Results obtained showed secured and seamless flow of information. Validation test proved system authenticity as built portal was accessed with different web browsers and identified users*.

Keywords: *Communication framework; database management; deregulated power industry; encryption, network architecture; transaction protocol*

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I. Introduction

Many national and state owned electric utilities in most developed countries were forced to change their ways of doing business from vertically integrated to unbundled and open market systems due to changing global trends in electricity consumption and other compelling market forces in the nineties[1]. There are many and various reasons for this changesuch as inefficient system management, lack of situational awareness, irrational tariff policies, corruption, high growing demand without commensurate growth in supply and dwindling government resources to continue funding provision of electricity as a social commodity[2, 3, 4, 5]. This resulted in the creation of many operationally distinct and autonomous firms - Generation Companies (GENCOs),Transmission Companies (TRANSCO), Distribution companies (DISCOS) and Independent System Operator (ISO) - in the deregulated power industry from the previously bundled large integrated system that was operationally and structural unified [ref for unbundling & privatization]. In the Nigerian case, the Nigerian Electricity Regulatory Commission (NERC) performs the regulatory job while the Transmission Company of Nigeria (TCN) owned by the Federal Government serves as the Independent System Operator (ISO) with the GENCOs and DISCOs fully deregulated and commercialized[6,7].

Some of the major problems that hindered the efficient operation of the Nigeria electricity industry prior to de-regulation which the 2005 Nigerian Electricity Act tried address were monopolistic nature of Power Holding Company of Nigeria (PHCN), undue government interferences and bureaucratic bottleneck, high cost of energy arising from usually highly inflated estimated billing of customers, unsteady and inconsistent government policies and implementation, corruption, lack of organized, free and competitive market, lack of power sector situational awareness which has eroded investor confidence and made planning and control difficult, lack of automated nation-wide monitoring, supervisory and control mechanism, lack of open and secured access database[7,8].

While the deregulation, unbundling, privatization and commercialization succeeded in bringing more investment in the industry with reduced government expenditure, it created chaotic situation in the system. This is because power grid is one large integrated system where generation, transmission and distribution segments are interwoven and activities in any segments affects the whole system, just like the human body. There is

therefore the dire need to provide seamless information flow and data flow to ensure effective communication amongst the approved industrial participators.

Previous research work aimed at addressing this situation considered the design of information architecture for future power system in order to improving fault tolerance and scalability requirements[1]; and the design of a communication security architecture for smart grid distribution network which aimed at reducing the vulnerabilities in the distribution network[3]. Work has also been done in concepts, issues and design of power sensitive Network Architecture in wireless communication[4], and development of system architecture for cross border payment[5]. Further work has been done in the design of a network architecture and communication modules for guaranteeing acceptable control and communication performance for networked multi- agent systems[7], design of a Distributed Intrusion System in a multi-layer network architecture of smart grid by deploying an intelligent module in multi-layers of smart grid to detect and classify malicious data and possible cyber-attacks[8]. There are occasions users were prevented from accessing the database directly and in the web base application security[9, 10].

To the best of our knowledge, there has not been any attempt to provide a unified communication framework with requisite database to provide a seamless accessing and sharing of electricity data between the various electricity Distribution Companies (DISCOs) - that serve the end-users - and the Generation Companies (GENCOs), Transmission Company of Nigeria (TCN), Nigerian Electricity Regulatory Commission (NERC) and the Customers. The research therefore seeks to develop a communication transaction protocol, a securedarchitecture and a good communication interface to enhance proper handshake among the key players in the power sector[11, 12,13].

The remaining sections of this paper focused on the creation of a communication network interface, secured database, communication framework, and secured portal that will facilitate effective transaction among the key players. It went further to illustrate the implementation algorithm, discussed the results using a prototype database with validation tests and concluded with appropriate recommendation for its implementation in the Nigerian electricity industry.

II. Materials And Methods

Communication Network Interface

The methods used in achieving the holistic system design and development in this work are: the waterfall model in a top-down technique for software system development. The waterfall model defines the functional and non- functional requirements, the model design, the implementation, verification and maintenance. The functional requirement in this work specify what the intended design should achieve while the non- functional requirement specify how the design should meet the design requirements. In this work, it focuses on how communication flows among the major key players in the de-regulated power industry. These key players - GENCOs, TRANSCOs, DISCOs, the independent system operator (ISO) and the customers, which are the end-users[14].

Micro media Dreamweaver, MYSQL and PHP are the design tools deployed for good software development. Micro media Dreamweaver is used for web design and MYSQL was applied in database management system while PHP was used as a scripting language. Distributed network system architecture on a client- server platform is the architectural network adopted to develop the system. Asynchronous communication was used since there was request for an information and also the acknowledgement for the receipt of the information sent.[16]

The protocol adopted are the hypertext transfer protocol (HTTP) used to initiate connection from the client (web browser) to the server. Also the transmission control protocol/internet protocol (TCP/IP) was used to transfer information from the client to the server. A new model called modified POOLCO was developed to encourage competition in the deregulated power industry and at the same time encourage buyers choose from any GENCO of their choice, among others. The functional requirement for each key player in the de-regulated power industry was discussed taking cognizant of the data, process and output as shown in the energy flow diagram in Fig. 1.

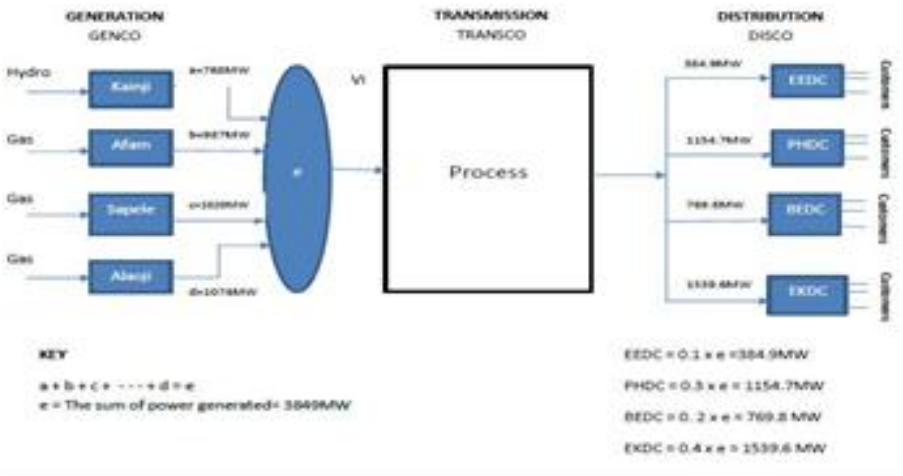

Fig. 1: *Energy flow diagram of Nigerian electricity industry*

It should be noted that the generation and distribution companies listed in Fig.1 are not the only ones in operation in the Nigerian deregulated electricity industry, but are used to illustrate the POOLCO model with which the authors demonstrated the communication framework proposed in this paper. Similarly the data for available generation capacities of the GENCOs where obtained from [Ref], the power allocations to DISCOs were illustrative. Due to the nature of deregulated and unbundled power system, it requires the existence of a well-defined communication framework and secured open access portal for data sharing and information dissemination.

Network Architecture

Distributed network architecture in a client-server approach was adopted. This involves having a centralized server (under the control of an Independent System Operators (ISO) "approved of" by all parties through government policy). As shown in Fig. 2. This server connects all other major players in the system.[17, 18]

Applicable Communication Protocol

The protocols observed are the Transmission Control Protocol/Internet Protocol (TCP/IP) and the hypertext transfer protocol (HTTP). The TCP/IP is responsible for Client-server applications are used to deliver services to the key players of the power industry across the Intranet (private network).It also supports one server being in charge of many clients and performs its operation affectively by observing the protocols that project adequate interfacing. The transfer of information between the client and the server while the HTTP is the protocol used to initiates connection from the client (web browser) to the server. This is demonstrated in Fig. 3 where the system is extended to 3-tier network architecture model whereby the first tier represents the client which contains the presentation layer (web browsers). The key players in the deregulated power industry alongside the customers are found at the presentation logic in the first-tier. They request for information and resources which are quickly met by the server so long as the authenticity of the request is verified.[16, 19]

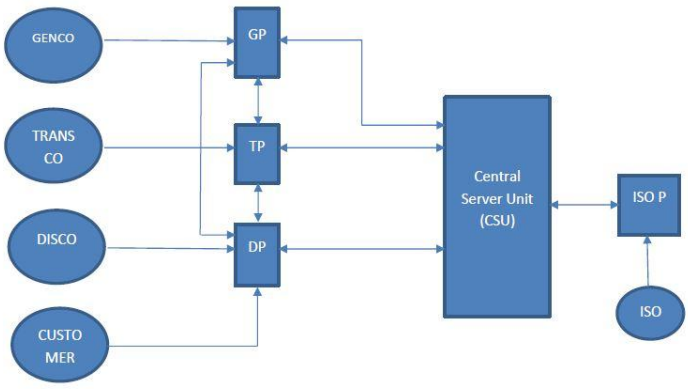

Fig. 2: Network architecture of the deregulated power industry

Where GP, TP, DP and CP refer to GENCOs, TRANSCO, DISCOs and customer portals respectively.

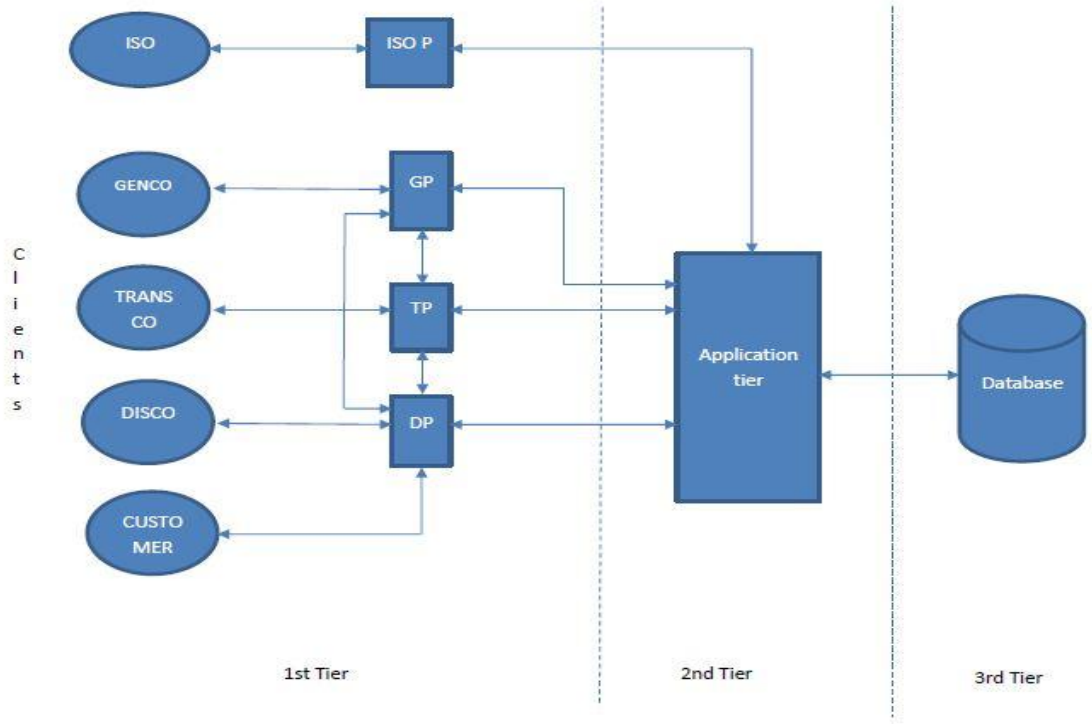

Fig. 3: Three-tier architecture for protocol illustration

The second-tier represents the application server and serves as middleware between the clients and database server. The operational decision making and application logic are done by the middle-tier.The middle-tier performs queuing and scheduling of user request, connection management and at the same time schedule back-end database transaction. The third- tier contains the data tier which represents the database where the information and resources needed by the clients are stored. The information and responses needed by each operator are taken care of by the protocol but the logic checks the authenticity of the information or data

III. Implementation

DISCOs Algorithm and Flowchart

The implementation steps involved in accessing the DISCO portal are as follows:
(i) DISCO initiates link to GENCO, TRANSCO and ISO through the portal for energy request(ii) DISCOs order and/or pay for power from GENCO.
(iii)DISCO pays for transfer of power through TRANSCO
(iv)GENCO acknowledges adequate deal (of buying energy and transfer of it) with DISCO. This is captured
(v)TRANSCO acknowledges receipt of payment to render services (Energy transfer) from GENCO to DISCO
(vi) ISO acknowledges both Request and Acknowledgement of Transactions between DISCO and TRANSCO
(vii)DISCO stores Energy and redistribute to valid customers accordingly.

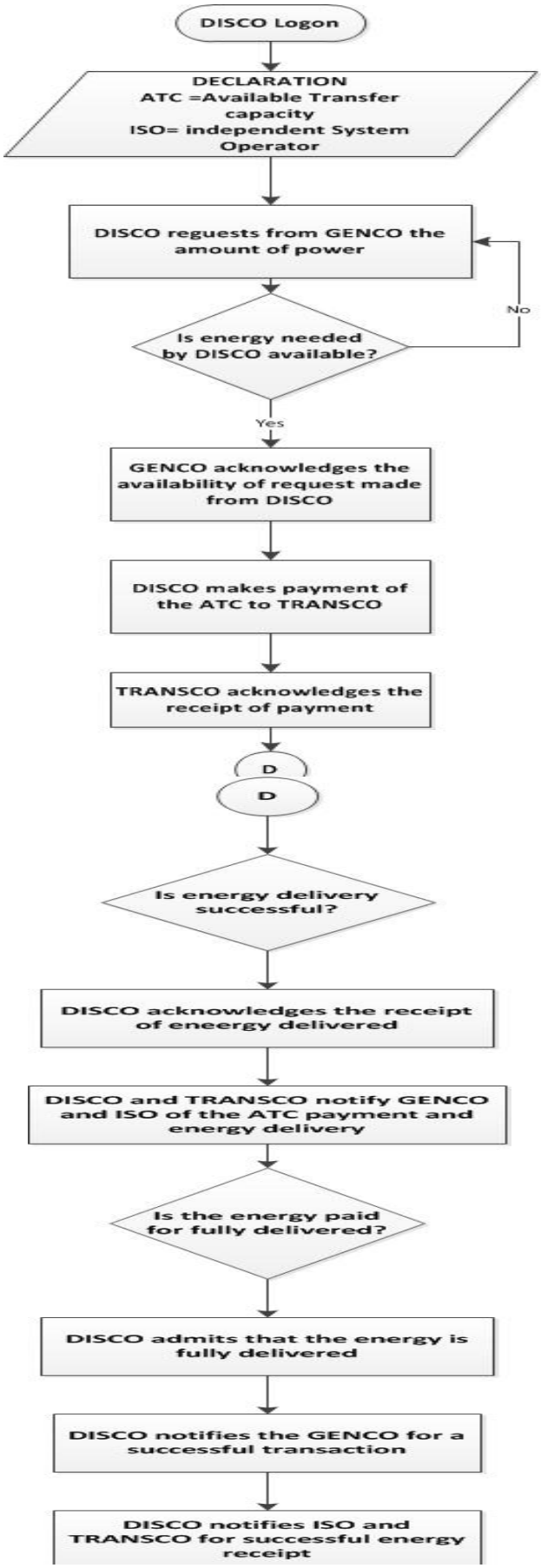

Fig 4: DISCO transaction flowchart

Security Implementation Measures Undertaken

Since each of the portal handles sensitive information and this makes security an important issue. Users activities in the portal may accidentally or intentionally reveal sensitive information and this will undermine the integrity of the portal. To avoid security breach, the following security measures were deployed:

- The use of unique username and password peculiar to every key player in the power industry as a strict measure to avoid unauthorized access to sensitive information in the portal.
- Each customer buying power from the DISCO must get registered first and he must have a unique access code as his username.
- SQL injection is prevented by filtering any input by the user. This enhances the integrity of the database.
- The ISO ensure that lines are not overloaded by preventing distribution companies from buying power that cannot be safely transmitted.
- Error messages due to login failure were ensured not to be detailed in order not to give malicious users information on how to hack into the system.
- Total loss of data were prevented by subsequent database backup using external memory devices as well as online backup.
- Validation as a security measure was adopted. This is used to confirm the authenticity of information supplied to the database.
- Passwords are stored in encrypted format ensuring that no one can have access to the plain text used for them.

Development of DISCOs Communication Portal

The DISCO module consists of all the processes and activities that involve the distribution companies. The portal is accessed by logging in with a username and password. A successful authentication takes the user to the portal homepage while failure to supply the correct username and password returns the user to the login page. Actions that can be taken include the ability to view the profile information such as the location and routes. The portal also allows the user to see past transactions occurring between the current GENCO and DISCO. The snapshot of DISCO's login, bidding, purchase and payment platforms are shown in Fig.5-8. Fig. 5 is the login page that allows either a DISCO or its customer to log in and conduct transactions. The bidding platform of Fig. 6 shows all the possible generation companies where Enugu Electricity Distribution Company (EEDC) – a referenced DICOs - can buy power from. Fig. 6 display the available power for sale from each of the power plants and the rate it may be purchase. Logging into this page will permit EEDC to have varying options where to buy from.

Fig. 5: DISCO log in page

Fig. 6: DISCO power bidding page

When it decides from which GENCO to buy from, the DISCO then logs into page shown in Fig. 7 to complete the purchase processes and makes payment at the page shown in Fig. 8. The actual payment is handled by other companies involved with online payment processing.After In this work, the transaction protocol is implemented in the software designed.

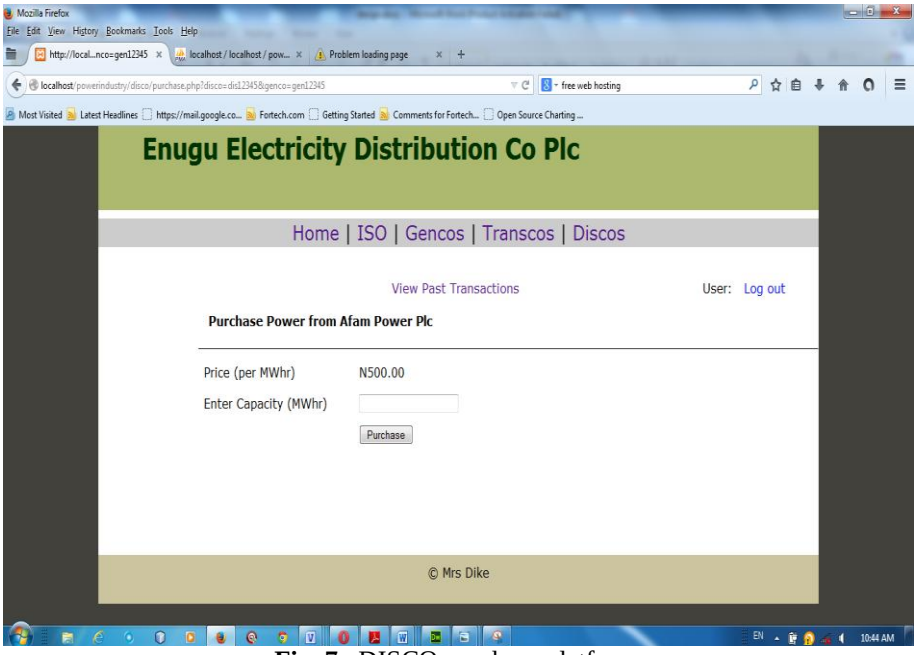

Fig. 7. DISCO purchase platform

Fig. 8: DISCO payment page

IV. Results And Discussion

The results obtained resolves around the implementation of the system algorithm, flow chart as well as the actual testing of the demonstrative database development which solidifies the validation of the designed work.

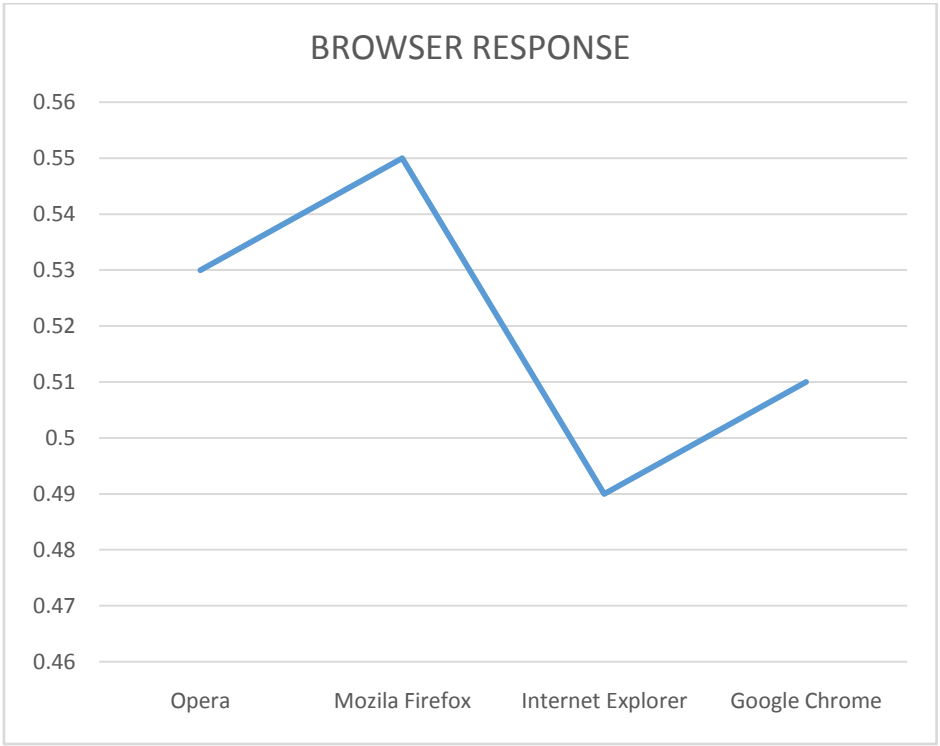

Fig. 9: Browser response time for portal validation test

Fig. 10: DISCOs portal performance evaluation test result

After the DISCO portal had been designed and developed validation tests were carried out for all the portals by users from Enugu Electricity Distribution Company (EEDC) as client 1, staff of NERC Owerri office as client 2, staff of National Institute of Information Technology (NIIT) Owerri office as client 3, staff of FUTO Computer Center as client 4 and 5th client is a field staff of Abuja Electricity Distribution Company (AEDC). The tests were structured for numerical values ranging from 1 to 5 representing poor, fair, good, very good and excellent respectively. The measured attributes were (i) availability representing ability to be accessed by a client via the internet (ii) functionality representing working as expected. Functions tested included registration and authentication of customers and operators; power transactions and payments (iii) accessibility of portal (iv) portability implying ability of the portal to migrate from one server to another on different hardware and software platforms (v) content relating quality of material make-up of the portal (vi) compatibility denoting how it could work with different web browsers (vii) user friendliness – ease of portal utilization by users without difficulty. Based on these criteria, results obtained as shown in Figs. 9 and 10 showed good performances of the portal under varying conditions. Also, the security of the developed system was able to dictate attempts to log in illegally and identified approved users. The clients also tested the portal using four different browsers to determine the time it will take to access data using EEDC as a case study. Results obtained as shown in Fig. 10 showed very fast response with all the commonly used browsers, with internet explorer recording the fastest time with this portal.

V. Conclusion

For an effective and smooth running of Nigerian deregulated electricity power system, a well-defined transaction protocol and communication interface should be implemented. This work has developed a conceptual framework for this taking recognizance of network architecture and topology. A workable communication channels for effective hand shake between the Nigerian Electricity Distribution companies and all requisite groups in the deregulated power industry has been created. The network architecture to interconnect these operators was designed. The client-server architecture model was adopted due to the distributed nature of the system. In order to enable the sharing of important information amongst these operators, a database system was developed. A web portal was developed for each of the operator so that transactions can be conducted through the network. With the distributed system, each operator can log in to his own portal to manage his own information as well as view market information of the operators. The system developed was simulated; and validation and functional tests results obtained showed good performances.

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