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An Effective Communication Architecture for Nigerian Electricity Market: A Panecea for Electric Power Stability And Economi C Growth

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ABSTRACT : *The work presents the development of an appropriate communication protocol, and secured portal that will facilitate effective transaction among the key players: Generation Companies (GENCOs), Transmission Company (TRANSCO), Distribution Companies (DISCOs) and the Independent System Operator (ISO) in the deregulated Nigerian power industry. This enhances proper handshake among these operators thereby improving overall system operational efficiency. The Client-Server architecture was adopted to develop a communication network in a Mesh format to give a multi-access link to the key operators in the power sector. This is a modification to the current ring format which does not give distributed access. The Adobe Dreamweaver is adopted as the design tool, while PHP (PHP Hypertext Preprocessor) is used as a scripting language and MYSQL database is used as the database management system. Results obtained showed secured and seamless flow of information for the entire system. One way and two ways access codes authentication were used for power key players and Independent System Operator respectively. The portal built was encrypted across the network to facilitate efficient E-payment transaction. The validation test result proves the authenticity and integrity of the entire system as the portal can be accessed with different web browsers and has the ability to identify individual user.*

KEYWORDS< *Communication Architecture, deregulated power industry, effective transaction, authentication, .database management system.*

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I. INTRODUCTION

Electric Utilities in the past has been faced with vertical integration and monopoly of regulation and until de-regulation, larger electric utilities performed all of the functions of generation, transmission, distribution and electric power sales, although, small firms did small generation- transmission or distribution and sales [1.] De-regulation weakened the supremacy of vertical integration and gave room for the splitting of entities in the electric power systems thereby gave room for competitions among the keys players in the power industries. Nevertheless, with the advent of this restructuring exercise, Nigeria has been faced with incessant power outages as a result of poor communication among the country's electricity key players - Generation, Transmission, Distribution, System Operator, Regulatory Agency and Customers [2] . For proper operation of the distribution system, different firms which were empowered from various geographical location, give rise to the emergence of Discos. However, to ensure fair play and provide adequately secure grid, government retained full ownership of the main transmission grid, thereby making it to become a neutral, natural monopoly subject to regulation by public authorities. So to overcome the monopolist characteristic, there has to be establishment of new legal and regulatory framework offering third parties open access to the transmission network. So, it was deemed necessary to introduce an independent body called Independent System Operator (ISO), to checkmark the excesses of the generation companies (GENCOs), transmission companies (TRANCOs) and distribution companies (DISCOs) [2]. The worst of it all is the irrational tariff inputted to the customers as a result of huge debt burden given to the Distribution companies. Therefore, each of the key players must have its own portal and this is controlled and monitored by the Independent System Operator (ISO). To prevent inefficient system management and irrational tariff policies, the Nigeria power industry was deregulated. One of the first steps in the restructuring process of the power industry was the separation of the transmission activities from the electricity generation activities. The next step was to introduce quasi competition in generation activities. Full competition will emanate through the creation of power pool, provision of direct bilateral transaction or bidding in the spot markets [1-3]

Two levels of competitions are permitted in a de-regulated electric power industry. They are the wholesale (generation and transmission) and retail (distribution and customer sales) levels. At wholesale level, GENCOs produce and sell bulk quantities of electric power to very large industrial customers. These bulk quantities of power are moved over the TRANSCOs transmission system. This is likened to a railroad which conveys electricity a long distance, but it reaches only one or two points in each community where they do business, so that individuals get power at low price.

. The three basic ways these can be done are: POOLCO, bilateral trading or power exchange [1] .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. A modified POOLCO method is adopted in this design to facilitate transparency, cost reduction and proper communication handshake among the key players in the deregulated power Industry

Previous research work discussed the need for electric power pool to make electricity affordable [1] and also a communication framework for the distribution companies to improving proper handshake among the entities in reconstructed power system taking cognizance of the Nigerian energy reform act [2-3]. Another work introduced a parallel and distributed processing technique to solve the problem of effectively coordinating the various entities in a reconstructed power market [4], and also the need for providing a reliable and efficient communication system by the combination of the rank metric scheme and MIMO using a Max-domain precoder [5]; and the need for proper monitoring and data management system so as to make electric utilities more sustainable by the introduction of 5G wireless networks [6]. Another work affirmed that generation in a distributed network can reduce the distribution losses as well as cost of power generation [7]; also another work pointed out that the exchange of data and information regarding weather level and generation forecasting is a requirement for an automated grid together with price optimization [8]; and the design of a communication security architecture for smart grid distribution network which aimed at reducing the vulnerabilities in the distribution network [9]. Work has also been done in concepts, issues and design of power sensitive Network Architecture in wireless communication [10,] and development of system architecture for cross border payment [11]. 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 system [12], also the 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 [13].

The remaining sections of this paper focused on the creation of a data and signal requirement, a novel modified Poolco architecture, database design, communication framework, and secured portal that will facilitate effective transaction among the key players. It also illustrated the implementation algorithm, discussed the results using a prototype database with validation tests and the paper was concluded with the need for the Federal Government of Nigeria to implement this piece of work in the deregulated power industry. .

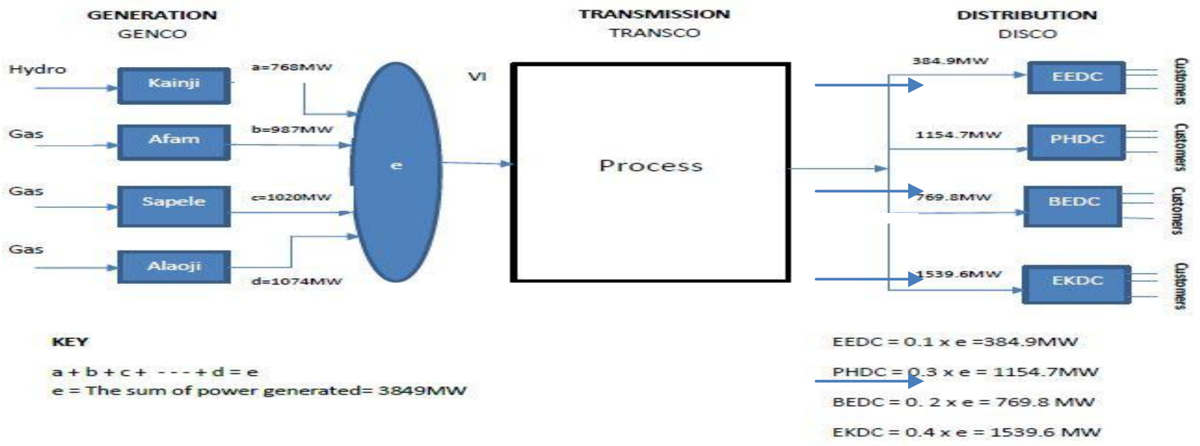
II. MATERIALS AND METHODS

The methods used in achieving the holistic system design and development in this work define the functional and non- functional requirements, the model design, the implementation, verification and maintenance. The functional requirement in this work specifies what the intended design should achieve while the non- functional requirement specify how the design should meet the design requirement. In this work, it focuses on how communication flows among the major key players in the de-regulated power industry. These key players are: the generation companies (GENCOs), the transmission company (TRANSCO), the distribution companies (DISCOs), the independent system operator (ISO) and the customers, which are the end-users.

DATA AND SIGNAL REQUIRMENTS:

The functional requirement for each key player in the de-regulated power industry encompasses the data, process and output of the information from the different GENCOs in a MIMO format to the individual DISCOs as shown in the data flow diagram in fig.1

Fig.1: Data flow diagram



The design took only four generation companies among the ten generation companies in Nigeria for illustration purposes. The transmission company is also aware of the amount of power generated by Individual GENCOs in Nigeria. The same applies to Distribution companies as only four DISCOs are used for illustration. The total data generated is pooled into one module before different DISCOs receive based on the available power using an assigned multiplier for each Distribution company. . The system to be developed is aimed at coordinating the activities of the key players in the deregulated power industry. In order to achieve effective interaction, there should be a well-built communication channels among the operators and the monitoring body. It can be seen from figure 2, that the Independent System Operator (ISO) has access to the information flowing among the operators thereby doing the work of coordination and control. The GENCO generates the power which is purchased by the DISCO and transmitted to the customers through the transmission lines owned by the TRANSCO. The customer on the other hand buys power from the DISCOs and lay complaints to the DISCO in his region for poor services. If the customer is not satisfied by the DISCO attitude after the complaint, the next alternative for complaint is the ISO. Fig. 3 below shows how these key operators communicate and how energy flows from the respective sources to the destination.

The communication flow is supported by transmission control protocol and Internet protocol (TCP/IP) and hypertext transfer protocol (HTTP). Protocols define the set of rules defining the format of the data. It also defines whether the transmission is synchronous or asynchronous. Asynchronous transmission describes communication which data can be transmitted intermittently rather than in a steady stream. In other words, asynchronous communication supports send and acknowledgement paradigm. In this work, the DISCO makes a request from GENCO and TRANSCO and receive acknowledgement from them before payment is made. At the same time, the ISO received acknowledgement from the DISCO that the power delivery was successful and was done according to policy. More so, the information and responses one needed is taken care of by the protocol but the logic checks the authenticity of the information or data. In this work, the transaction protocol is implemented in the software designed.

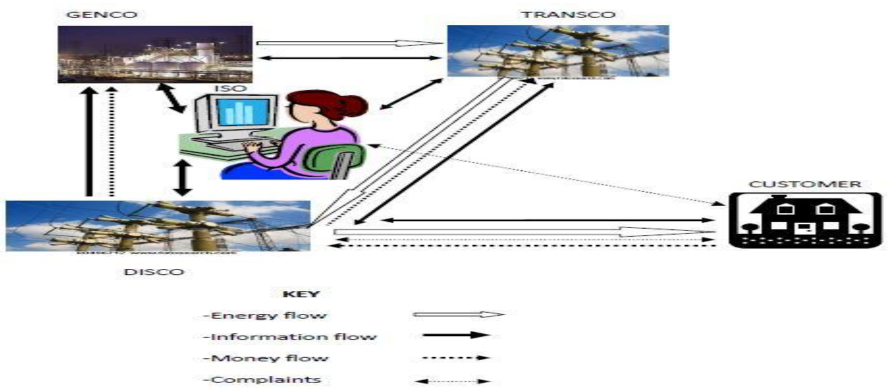


Fig.2: DEREGULATED TRANSACTION PROTOCOL

- **FUNTIONAL NETWORK DIAGRAM**

The functional network diagram shows the symbolic power flow of the system by their functions and this functional diagram explicitly explain the modified POOLCO model. Here, there are many generating companies called the GENCOs, although, few GENCOs were chosen to give illustration of their activities in the functional network diagram shown in fig. 3. Each GENCO generates energy and transfers to the DISCO directly through the TRANSCO after making the transaction known to the ISO. . On the other hand, the TRANSCO informs the ISO of the transaction between his company and DISCO and convinces the ISO of the availability of the line. The ISO always get the update of what is about to happen and the acknowledgement of what has already happened from the GENCO, DISCO and TRANSCO. From fig.3. below, the solid line is the energy flow while the broken lines are for information flow. The double arrow head drawn in the network shows the send and acknowledgement process. The proper hand shake among the operators enhances seamless flow of information and this reduces situational unawareness.

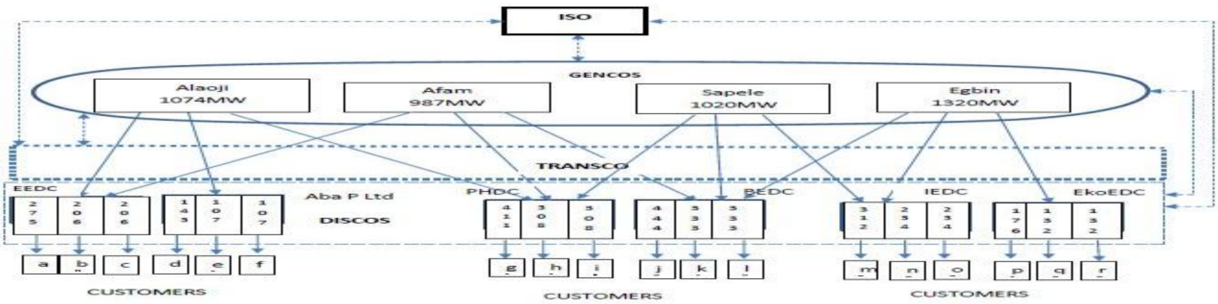


Fig.3: Functional network diagram of the deregulated Nigeria power industry.

The communication aspect of this work shows clearly how all the key operators interact among themselves in a send and acknowledgement manner. This is Asynchronous form of communication. The GENCO receives the acknowledgement of the power delivered to the DISCO through the TRANSCO. The DISCO makes payment to the GENCO and TRANSCO and acknowledges receipt of payment to them. The customers send their complaints to the ISO and DISCOs and acknowledges the receipt immediately. Finally, the ISO regulates and monitors the activities of the GENCO, TRANSCO and DISCO. This is shown in fig. 3.3 below:

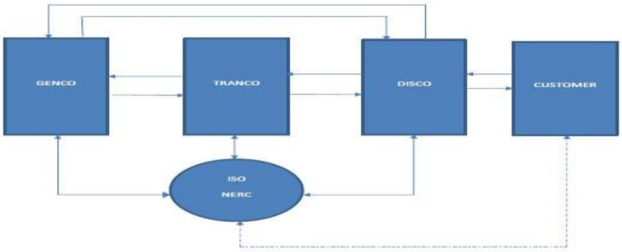


Fig 4: Communication Requirement

Many factors helped to make the communication aspect in the de-regulated Nigeria power industry a success. These factors are:

- RELIABILITY: The system must have high availability with little or no failure rate.
- USABILITY: The system was developed with adequate user interface. This makes it easier for the user to navigate and become familiar with the system.
- PORTABILITY: The system was developed with microelectronic devices that are networked in the platform of any compatible browser.
- SECURITY: The system was protected against unauthorized usage. This was achieved by implementing login mechanism in all the portals.
- MAINTAINABILITY: This is achieved by ensuring bugs recovery at the shortest downtime. This is implemented by employing good programming style, keeping good documentation of the system and validating the source code.

III. IMPLEMENTATION

DESIGN ALGORITHM AND FLOW CHART

A. GENCO ALGORITHM

- Is Energy (KW) generated by the GENCOs?
- At what level did each of GENCOs generate?
- What is the total generated Energy (KW)?
- What is the distributing/Sharing ratio among DISCOs?
- What are the guiding conditions for the sharing/distribution formula
- Communicate to the TRANSCOs, ISO and DISCOs on policies
- Are apportioned energy paid for?
- Are apportioned energy released to TRANSCOs/DISCOs?
- Action taken, generation maintained and stabilized.

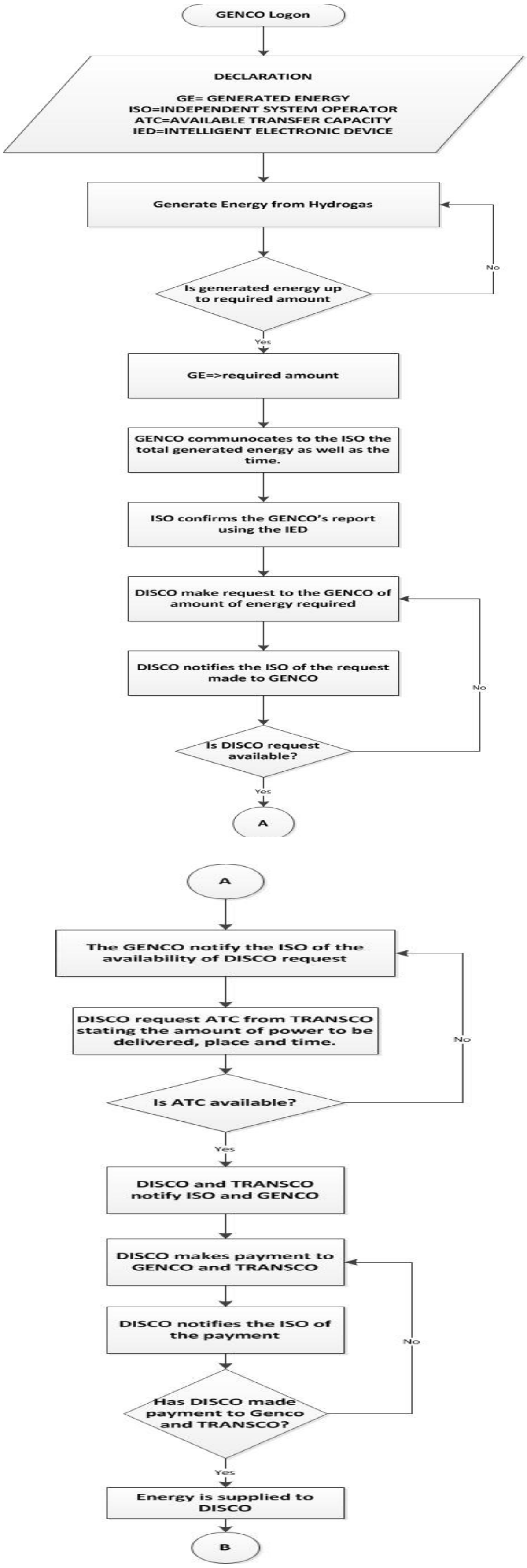


Fig. 6: GENCO flowchart

B. TRANSCO ALGORITHM

- GENCO has access to TRANSCO portal and initiates communication
- GENCO directs portal to deliver 1074MW to DISCOs through TRANSCOs
- GENCO pays for service delivery to TRANSCO
- TRANSCO acknowledges payment
- TRANSCO initiates transfer of 1074MW to DISCO
- TRANSCO delivers 1074MW to DISCOs
- TRANSCO receives acknowledgement of delivery

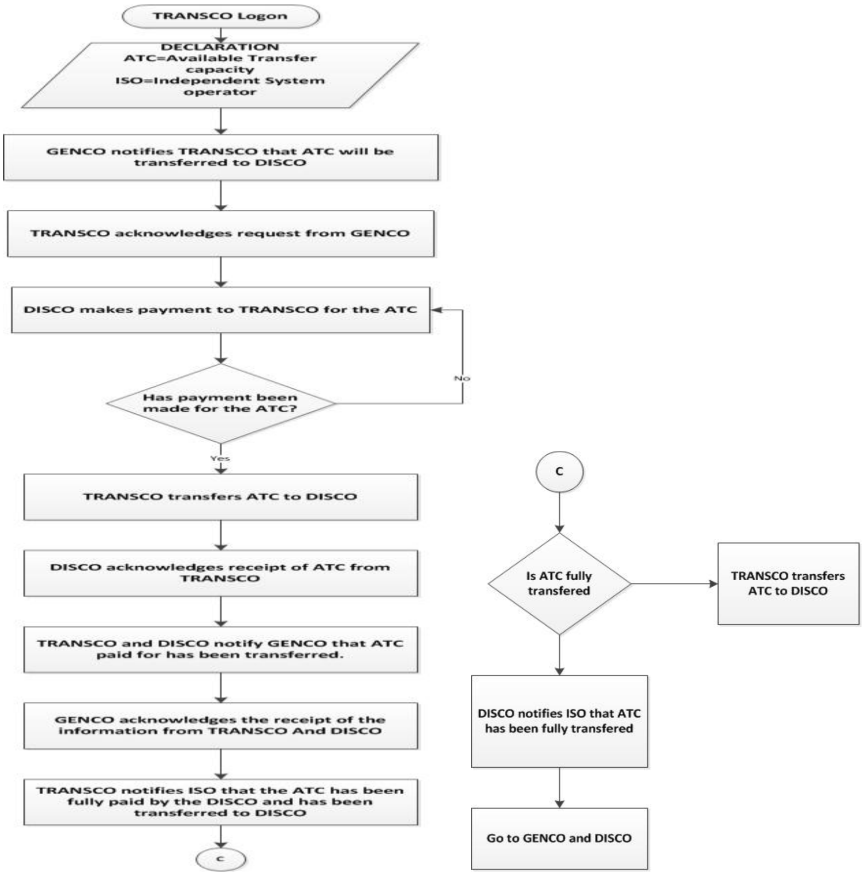


Fig.7: TRANSCO flowchart

DISCO ALGORITHM

- DISCO initiates link to GENCO, TRANSCO and ISO through the portal for energy request
- DISCOs order and/or pay for (1074MW) energy from GENCO
- DISCO pays for the transfer of Energy from GENCO through TRANSCO
- GENCO acknowledges adequate deal (of buying energy and transfer of it) with DISCO
- TRANSCO acknowledges receipt of payment to render services (Energy transfer) from GENCO to DISCO
- ISO acknowledges both Request and Acknowledgement of Transactions between DISCO and TRANSCO
- DISCO stores Energy and redistribute to valid customers accordingly

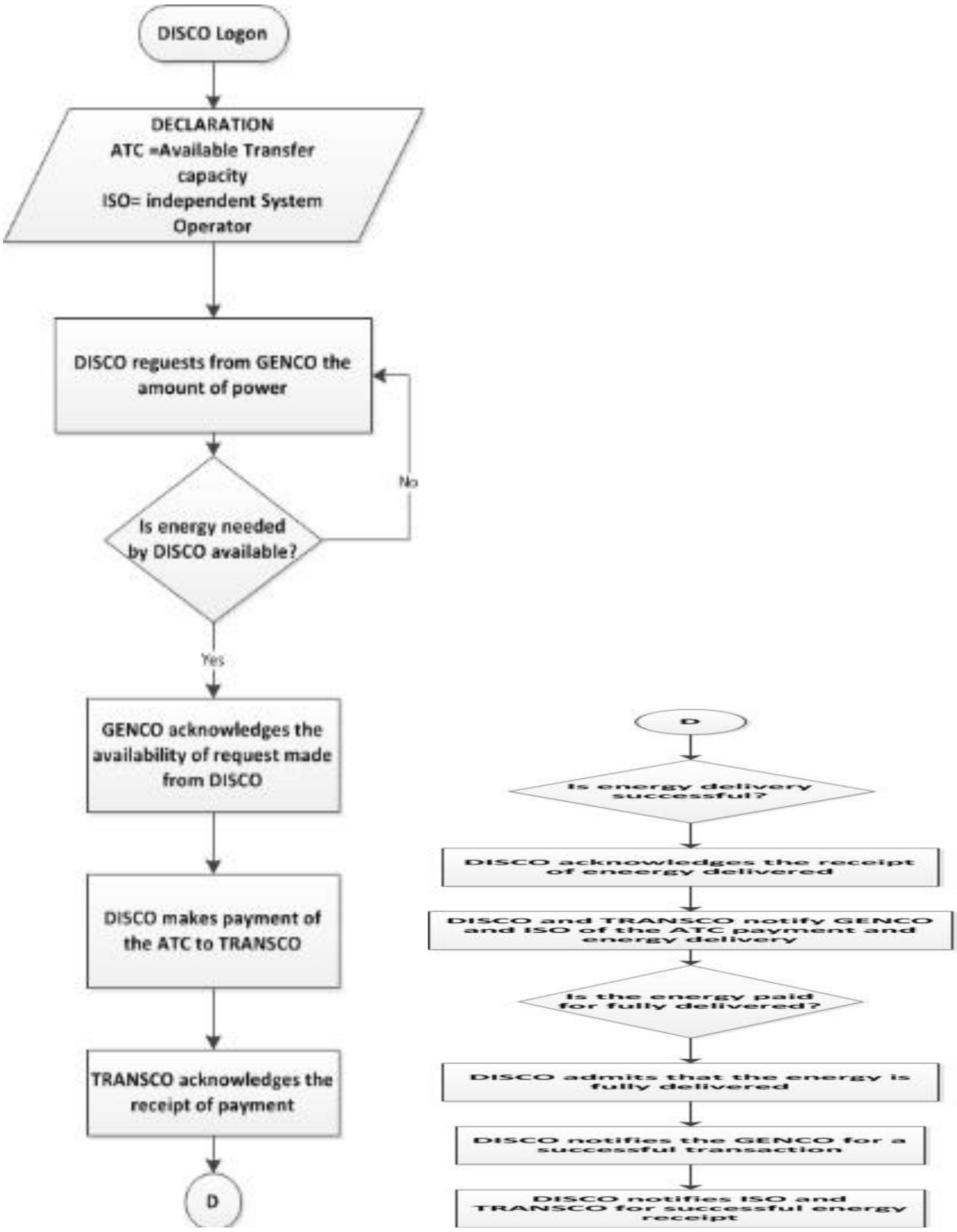


Fig.8: DISCO flow chart

ISO ALGORITHM

- ISO makes policies and power-sharing ratios for DISCO
- Connects to DISCO, TRANSCO and GENCO
- Monitors and controls transaction among the operators
- Sanctions operators violating the policies
- Approves and records successful transactions

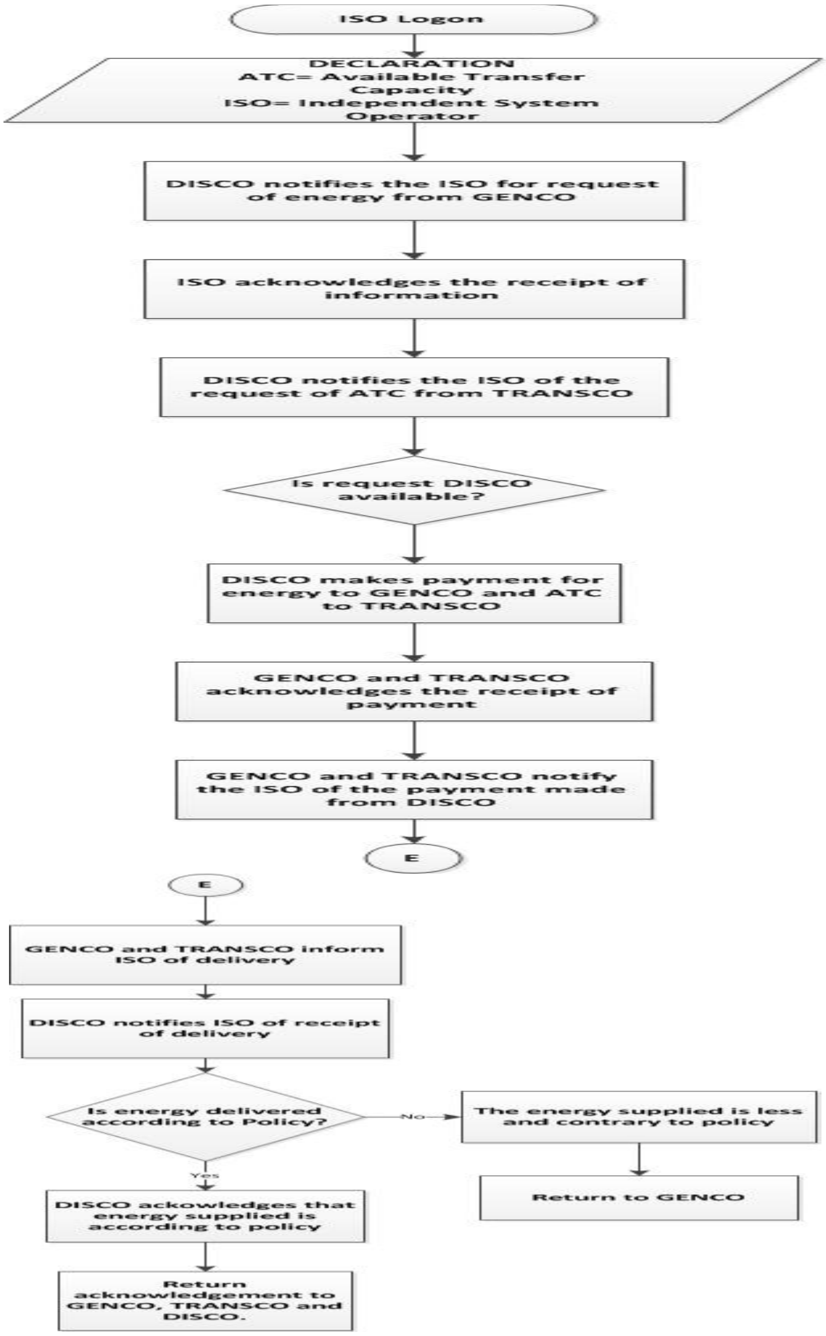


Fig.9: ISO flow chart

SECURITY MEASURS

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 Communication Portals

- **Home page**

The home page is the first page presented to the user when he connects to the system using a web browser. It contains the links to view the licensed operators in the area of the GENCO, DISCO and TRANSCO. It also has the link to the ISO portal.

Fig. 10: Home page

GENCO Portal Login Page

Each operator has a different login page where the username and password are captured for authentication. A successful login takes the operator to his homepage, while any error due to login failure is displayed to the user.

Fig. 14: GENCO login page

DISCO Portal Login Page

The login page allows either a DISCO or a customer to the DISCO to log in and conduct transactions. The diagram is shown below.

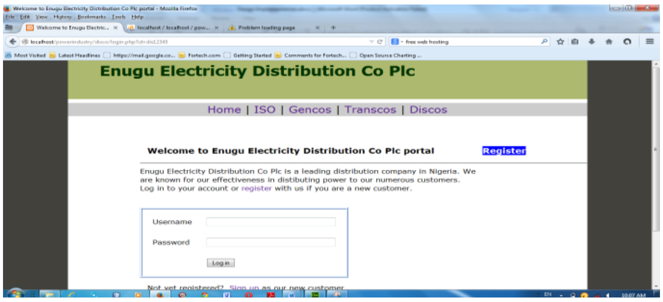


Fig. 15: DISCO login pages

TRANSCO portal login page

This page allows the transmission company to log in to his portal to view and perform transactions.

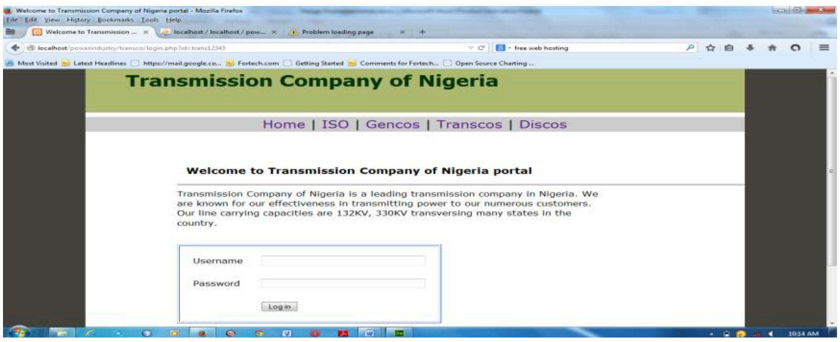


Fig. 16: TRANSCO login page

ISO Portal Login Page

The login page of the ISO is highly protected with a two-stage authentication. This means that after the username and password have been successfully authenticated, an access code is required to reach the ISO portal home page.

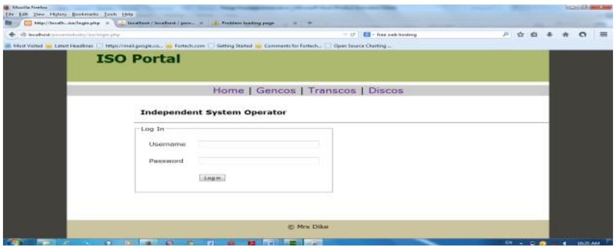


Fig. 18: ISO Portal Login page

GENCO Portal Transaction page

DISCO Payment

This page allows the DISCO to make payment to the GENCO. The actual payment is handled by other companies involved with online payment processing

Fig. 23: DISCO Payment page

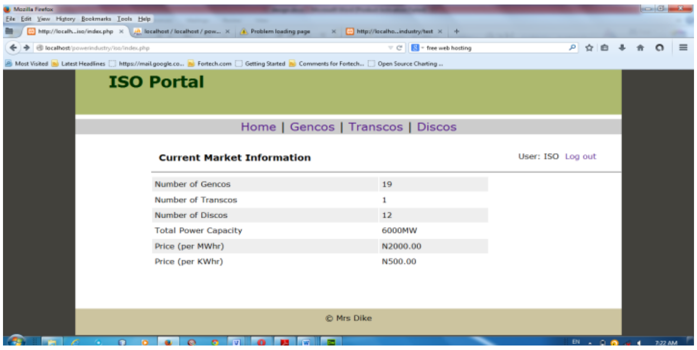


Fig. 25: ISO Portal Homepage

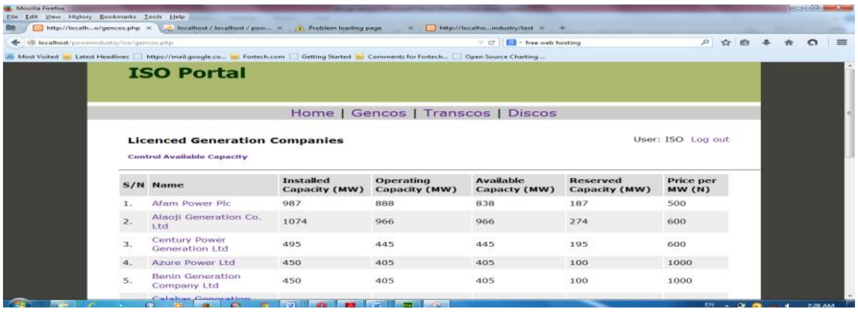
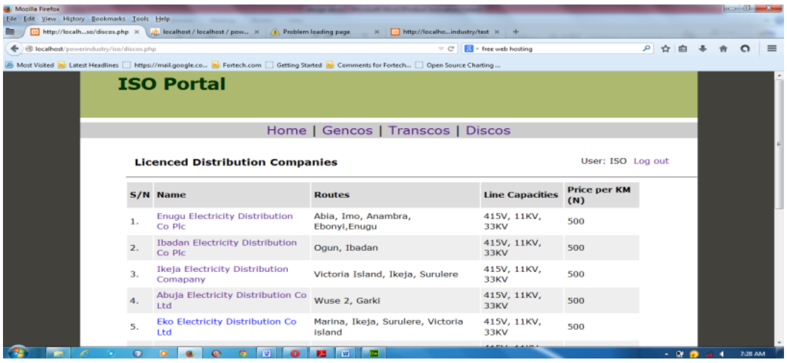


Fig.26: ISO View of Generation Companies profile



ISO Portal

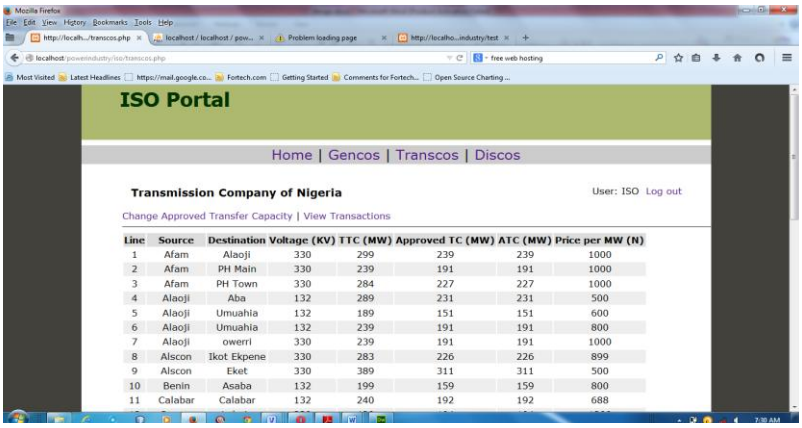
Home | Gencos | Transcos | Discos

Licenced Distribution Companies

User: ISO Log out

S/N	Name	Routes	Line Capacities	Price per KM (N)
1.	Enugu Electricity Distribution Co Plc	Abia, Imo, Anambra, Ebonyi,Enugu	415V, 11KV, 33KV	500
2.	Ibadan Electricity Distribution Co Plc	Ogun, Ibadan	415V, 11KV, 33KV	500
3.	Ikeja Electricity Distribution Comapany	Victoria Island, Ikeja, Surulere	415V, 11KV, 33KV	500
4.	Abuja Electricity Distribution Co Ltd	Wuse 2, Garki	415V, 11KV, 33KV	500
5.	Eko Electricity Distribution Co Ltd	Marina, Ikeja, Surulere, Victoria island	415V, 11KV, 33KV	500

Fig. 27: ISO View of Distribution Companies



ISO Portal

Home | Gencos | Transcos | Discos

Transmission Company of Nigeria

User: ISO Log out

Change Approved Transfer Capacity | View Transactions

Line	Source	Destination	Voltage (KV)	TTC (MW)	Approved TC (MW)	ATC (MW)	Price per MW (N)
1	Afam	Alaoji	330	299	239	239	1000
2	Afam	PH Main	330	239	191	191	1000
3	Afam	PH Town	330	284	227	227	1000
4	Alaoji	Aba	132	289	231	231	500
5	Alaoji	Umuahia	132	189	151	151	600
6	Alaoji	Umuahia	132	239	191	191	800
7	Alaoji	owerri	330	239	191	191	1000
8	Alscon	Ikot Ekpene	330	283	226	226	899
9	Alscon	Eket	330	389	311	311	500
10	Benin	Asaba	132	199	159	159	800
11	Calabar	Calabar	132	240	192	192	688

Fig. 28: ISO View of TCN

IV. RESULTS AND DISCUSSION

RESULTS

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.The modified Poolco model also known as functional network architecture adopted improved the seamless flow of information among the key players in the power industry.. This is demonstrated by the functional flow chart of the design. There is quick message sent and acknowledgement of the receipt of the information. This shows that delay in the transaction process among the key players in the deregulated power industry is mitigated. The implementation of the system could be done once the design and information flow processes detailed in chapter three of this work were successfully completed. Screen shots showing the graphic user interface of the communication processes among the key players in the deregulated power industry was demonstrated using a functional data base. This is demonstrated by showing the browser response time from the portal validation test as shown in fig 9 and also the portal performance evaluation test result as shown in fig.10.

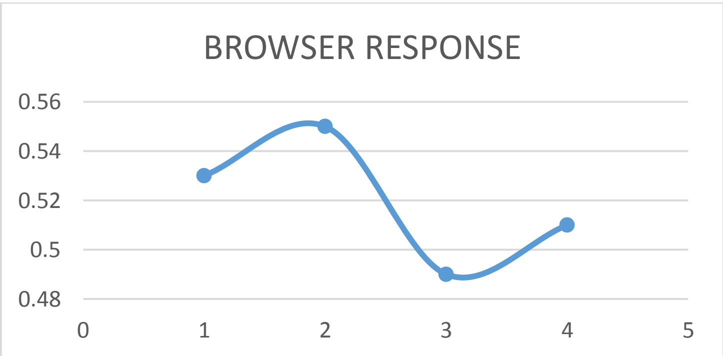


Fig. 9: Browser response time for portal validation test

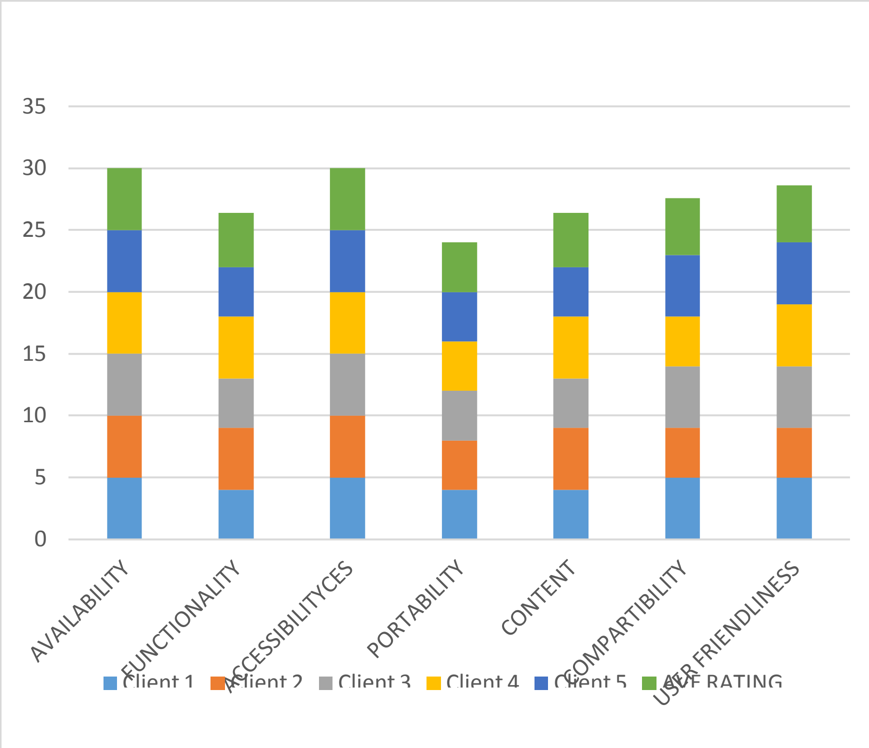


Fig. 10: DISCOs portal test result Performanc Evaluation

IV. DISCUSSION And CONCLUSION

DISCUSSION

The work done so far, shows the effective transaction processes going on among the key operators in the power sector. The communication protocol adopted encourages seamless flow of information, since it obeys send and acknowledgement format.Adequate measures are taken to ensure security in the operators' portals. This is demonstrated by the authentication and validation exercise.The 3-tier client- server model adopted shows that the designed work is in conformity with the existing technology. The client-server architecture model was adopted due to the distributed nature of the system on the platform of a well-designed mesh topology for the operational activities of the operators for flexibility and scalability of transaction activities, as against the current nature of the power sector that is of a ring topology format.The transaction protocol in the deregulated power industry is a demonstrative one as the system was able to show the proper handshake among the GENCOs, TRANSCOs, DISCOs, ISO and the customer. The ISO was able to monitor the transaction going on in the GENCO, TRANSCO and DISCO portal. The ISO regulates the transaction by making sure that available transfer capacity for line was not exceeded. This was shown in the database by the error message received when one is trying to buy the quantity the line cannot carry.. The result shows the effectiveness and workability of the transaction protocol and the demonstrative database of the system and help to reduce situational unawareness in the current power sector.The snapshot showing the pictures of the transaction process carried out shows that the designed work was implemented successfully. To further validate the design, different type of text like smoke text, functional text system text and acceptance test was carried out. Finally, the design work is workable and can be adopted by the federal government to boost power sector COMMUNICATION efficiency in Nigeria.

Conclusion

In this work, the network architecture to interconnect the operators (GENCOs, TRANSCOs, DISCOs) in the deregulated power industry was designed. The client-server architecture model was adopted due to the distributed nature of the system on the platform of a well-designed mesh topology for the operational activities of the operators for flexibility and scalability of transaction activities, as against the current nature of the power sector that is of a ring topology format. In order to enable the sharing of important information amongst these operators, a secured database system was designed using MySQL database software.

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