Scientia Africana, Vol. 18 (No. 2), August, 2019. Pp 91-100
© Faculty of Science, University of Port Harcourt, Printed in Nigeria **ISSN 1118 – 1931**

CONSTRAINT SATISFACTION MODEL FOR EFFICIENT ELECTRICITY DISTRIBUTION IN PORT HARCOURT CITY

[1]Nuka Nwiabu and [2]Grace B. Michael.

[1,2]Department of Computer Science, Rivers State University, Port Harcourt, Nigeria
nuka.nwiabu@ust.edu.ng, gmbmichael2018@gmail.com
Corresponding Author: gracemichael2002@gmail.com, ***Tel.: +2348036674985***

Received: 31-05-19
Accepted: 10-06-19

ABSTRACT

Efficient electricity distribution and utilization is a challenge in developing cities like Nigeria. The purpose of this research is to model constraint satisfaction in electricity distribution in Port Harcourt city which have two distribution feeders located at CFC Bus stop and Trans Amadi area of Port Harcourt City. The research adopted constructive design and object oriented methodologies. Bayesian network was used in the distribution of (energy) electricity to critical, commercial and residential areas. Voltage distribution were analyzed in percentage, constrain satisfaction, using Bayesian model and it effectively distributed 59kv to critical areas, 30kv to commercial areas and 11kv to residential areas during working hours of the week days. Result shows that applying optimization scheduling distribution was efficiently implemented with maximum satisfaction.

Keywords: Constraint, Electricity, Distribution Generation, CSP, Bayesian network

INTRODUCTION

Constraints satisfaction can be viewed back to research in Artificial Intelligence in the sixties and seventies, Montanari (1974), Scene labeling was said to be the first formal constraint satisfaction carried out. In scene labeling, objects were used in recognizing and interpreting scenes by drawing the scene labeled problem. The aim of this was to identify lines or edges, in convex, concave, and concluding edges, however, awareness in the last two decades proves that these techniques can be used as steps to programming modeling, and problem solving with various concepts using a common platform and analytical frame work in constraint programming Lishinski et al., (2016).

A constraint could be seen as setbacks, limitations, barriers, fluctuation, and instability or regulates. The advantage of constraint satisfaction programming is based on the fact that it permits the modeling of a problem in simplified analysis and also provides a good method of solving the algorithms. Constraint satisfaction programs due to its capability of solving hard real-life problem and based on the strong theoretical foundation has attracted the interest of experts from other discipline who are also using these software in problem solving, Bartak (1999).

Constraint Satisfaction Problem (CSP) plays a major role in artificial intelligence; it can be applied in job-shop scheduling, planning and configuration domain. It can also be used to determine variables that satisfy constraints, or otherwise, show the non-existence of such assignment, Li et al., (2016). The aim of this work is to model constraint satisfaction in electricity distribution in Port Harcourt city and the objective includes:

i. To carry out a study on how schedule structure can be acquired easily using constraint satisfaction model.
ii. To create a model that removes any form of interruption or waste in electricity distribution.
iii. To ascertain the importance of applying constraint satisfaction in solving electricity distribution problems.

Several constraint satisfaction model has been developed for efficient electricity distribution, such as Planning of electricity power generation system under multiple uncertainties and constraint–violation levels by Quanch and Hoang (2017). Furthermore, according to Hu et al., (2014) in designing electricity for multiple sectors, multiple facilities, and multiple uncertainties constraint programming was applied to support regional electric power generation system (REPGS) under the condition of achieving development. Constraint satisfaction was applied in power sharing among control agent while ensuring satisfaction of accurate reactive power distribution to Island micro grids (IMGs) under diverse operating conditions, El-Taweel et al., (2017). Constraint satisfaction was considered in provincial-level for power planning models as a very principal source of power generation in Zhejiang province, constraint satisfaction was used for the different key performance indicators (KPI) to distinguish the difference in electricity demand scenarios used in development path and in providing lowest discounted cost, Mahmoud et al., (2019). Constraint satisfaction was also used as a natural way of computing problems such as mapping and assignment, graph color ability and system equations in theoretical computer science, Bian et al., (2016). While artificial intelligence (AI) is considered a flexible and efficient way of modeling and solving lots of real world scheduling problems, Wang et al., (2018).

MATERIALS AND METHODS

The methodologies used for this work are constructive research methodology and object oriented design methodology. Constructive research methodology is an actual procedure with relevant theoretically base findings that is relevant for the comprehension of research processes by Crnkovic, (2010). The steps involved are best suitable in achieving the aim of this research and it will give an in depth understanding of this research in acquiring a comprehensive understanding of the research area, it will aid in designing one or more applicable solutions to problem, demonstrating the solution feasibility, relating the result back to the theory and indicating their practical contribution. It will also explore the extensive ability of the results were most appropriate for the research, Oyegoke (2011), while, object-oriented methodology is defined by Powell-Morse, (2017) as the theoretical concepts and ideas developed during the analysis

Scientia Africana, Vol. 18 (No. 2), August, 2019. Pp 91-100
© Faculty of Science, University of Port Harcourt, Printed in Nigeria *ISSN 1118 – 1931*

stage and applied to object-oriented software development The object-oriented design methodology was applied because of the steps involved which includes; Requirement analysis, Domain analysis, System design, and Implementation which are best suitable in achieving the aim of this work.

The architectural design of the system is a procedure applied for different technicality and fundamental description of the module, procedure, or structure in a well detailed form to enable actual coding. The conventional approach to the software design process focuses on partitioning a problem and its solution into detailed pieces upfront before proceeding to the construction phase, Mekni et al., (2017).

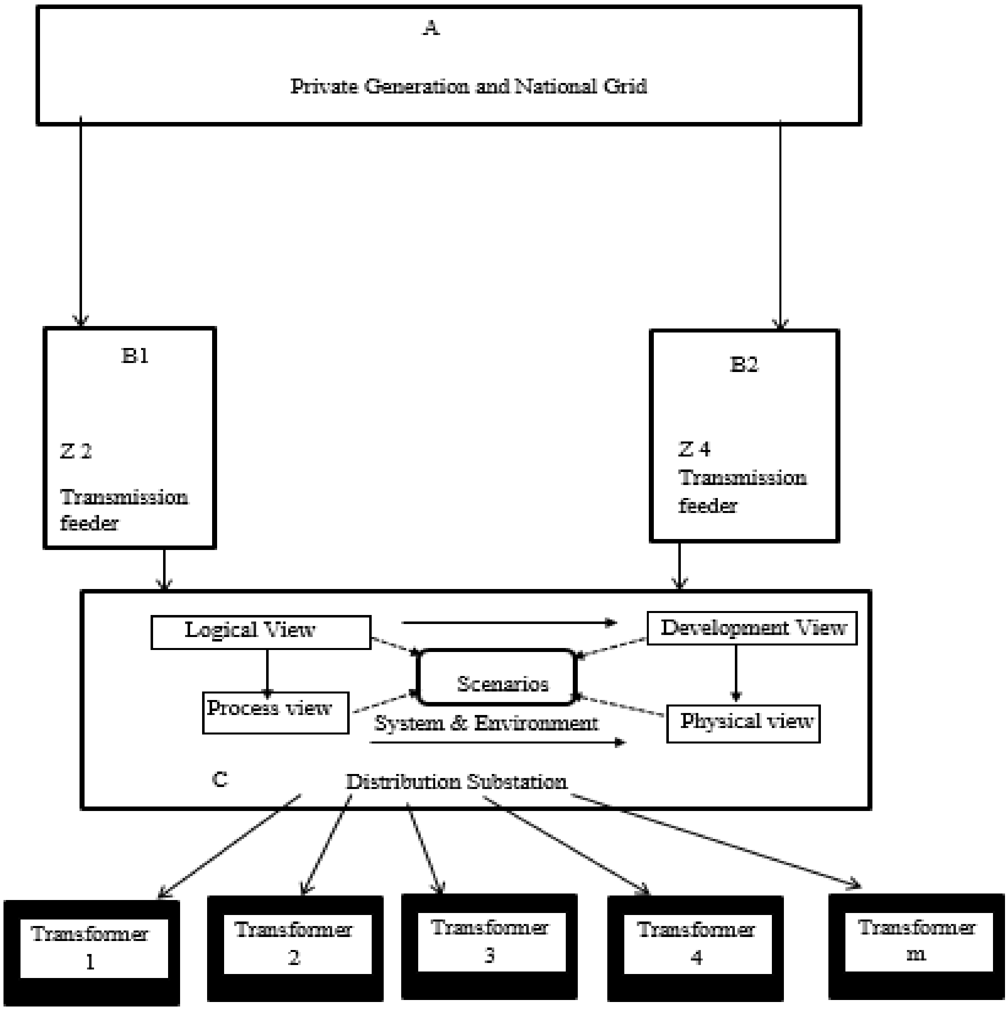

Figure I: System architecture for electricity distribution

The system architecture in figure 1 begins with the root of the database (private generation and national grid) which is classified as category A, the next is B1 and B2 representing the feeders (Z2 and Z4 Transmission feeders), and this is followed by category C (distribution substations system). The system software environment controls distribution process scenario, the process view illustrates system procedures and actions. The logically views is to ensure functionality of system and satisfaction of end users by the admin, the development view has to do with software management and implementation to ensure efficient distribution, the physical view represents the engineering connections between devices to detect distribution in different areas, (Kruchten, 1995). The arrows in group C signifies relationship between the nodes in the database distribution transmission with transformers. Let Private Generation and National Grid be known as A, Transmission feeder B1, Z2 = $\mathcal{X}$, Transmission feeder B2, Z4 = $\mathcal{Y}$. Therefore, distribution substation system which is the output channel C is given as total generated voltage (A), distributed to Z2 and Z4 feeders (B1 and B2), which gives distribution substation output (C). Equation (1) is the sum of what is received in x and y. While the total result is equal to c which is sum of what is distributed out.

$$x + y = c \text{ . ... Equation (1)}$$

$$or\ c = x + y$$

Equation (2) shows the distribution system, p_2 is the summation of production capacities $\sum p_2$, while m_i is equals summation of transmission capacities $\sum m_i$

$$\sum p_2 = m_i \text{ . ... Equation (2)}$$

Therefore, where production capacity $p = x + y$, transmission capacities is given

$$\sum_i^4 mi = M_1 + M_2 + M_3 + M_4$$

The Objective as seen in equation (3) is to make summation of production capacity greater than or equals to summation transmission capacity $\sum p_2 \geq \sum mi$

$$P(Mn|Mi) = \frac{P(Mn,Mi)}{P(Mi)} \text{... Equation (3)}$$

The national grid (A), is the input variable to the system which is the electricity Power generation source where transmission of bulk transfer of 1000 kilovolt or more electrical energy is being generated and distributed through transmission stations Z2 (B1) and Z4 (B2), to distribution substation feeders at different areas. Distribution substation (C), which are the transformers in the last category of distribution network transmits electricity to end consumers or collectors in the critical, residential and commercial areas through transmission control centers. Each day and weeks, distribution of electricity is received in batches of 50KV, 100KV and 1000KV depending on what is being generated. Variables in different areas includes: Commercial, Commercial and Residential. Domain which are voltage received daily and each week in baches are 50KV, 100KV, 1000. The Constraints in these areas could be burnt fuse, bad cables, faulty transformers, and poor transmission channels. Let area in Vi to Vj (critical,commercial, and residential) connect to each other. Let domain which is amount of voltage received for distribution in area Vi not be equals to what is distributed in area Vj. $C = \{(\forall Vi, Vj, such\ that\ Vi\ touches\ Vj,)\ Domain\ (Vi) \neq (Vj)))\}$, therefore, $V = \{CR, CO, RE = 50KV, 100KV, 1000KV\}$

$D = Vj, Vi = Domain\ Vi \neq Domain\ Vj$ to formulate in terms of variables, domain and constraint $V = \{CS = CR, CO, RE\} = (50KV, 100KV, 1000KV)$

$D = Mon\ 9am, Mon\ 11am, Mon\ 1pm, Mon\ 6pm, \ldots, Fr\ 11pm, where\ C = \forall i, j\ if\ Vi, Vj\ are\ co -$

Scientia Africana, Vol. 18 (No. 2), August, 2019. Pp 91-100
© Faculty of Science, University of Port Harcourt, Printed in Nigeria *ISSN 1118 – 1931*

$requisites, then\ CRi \neq CRj.$ The critical areas are central banks, hospitals, Government reserved areas (G.R.As), University institutions, and fire services. These areas are expected to have uninterrupted power supply, therefore, higher concentration are given to these critical areas during working hours of the days and on weekends. Commercial areas are business centers, examples are silver bird, Trans Amadi industrial area, Secretariat, and spar. Average concentration is given to these areas during working hours of the day from 8a.m to 5p.m for optimal distribution, while, residential areas where people reside are given lower concentration during working hours of the day because most persons leave for work and schools during the day to retire back in the evenings. In the evenings, average concentration is transmitted to residential areas from 5p.m in the evenings to 8a.m the following day, and uninterrupted average concentration on weekends is given to residential areas because most companies don't operate on weekends. Therefore, for efficient distribution of electricity by applying Bayesian network for optimal distribution let summation for distribution in residential area be given as summation of $M_{i,}$ i ranging from 1 to 4

$$\sum_{i=1}^{4} mi = M_1 + M_2 + M_3 + M_4 = 3 + 1 + 3 + 4 = 11$$

The result shows that distribution stopping point of lower voltage in residential areas be eleven percent (11%) during working hours of each day of the week as expressed. While for commercial areas, let the expression for average distribution be given as summation of Mi^2, i ranging from 1 to 4

$$\sum_{\text{i}=1}^{4} Mi^2 = M_1^2 + M_2^2 + M_2^3 + M_4^2 = 1^2 + 2^2 + 3^2 + 4^2 = 1 + 4 + 9 + 16 = 30$$

Therefore, distribution to commercial areas be given thirty percent (30%) of what is generated. For critical areas, let optimal distribution applying Bayesian network be expressed as summation of $M_{i,}$ i ranging from 1 to 3

$$\sum_{i=1}^{3} M\,i^2 = M_1^2 + M_2^2 + M_3^2 = (-1)^2 + 3^2 + 7^2 = 1 + 9 + 49 = 59$$

Therefore, distribution to critical areas will be given higher voltage of fifty nine percent (59%) of what is generated during working hours of each day and on weekends. While residential areas will be given average voltage of thirty percent (30%) of what is generated on weekends.

$$\sum_{\text{i}=1}^{4} mi^2 = M_1^2 + M_2^2 + M_2^3 + M_4^2 = 1^2 + 2^2 + 3^2 + 4^2 = 1 + 4 + 9 + 16 = 30$$

Also, commercial areas on weekends will be given lower voltage of eleven percent (11%) of what is generated on weekends.

$$\sum_{i=1}^{4} mi = M_1 + M_2 + M_3 + M_4 = 3 + 1 + 3 + 4 = 11$$

RESULTS

The energy of 1000 kilovolts generated from the national grid and other private distribution sectors is received and moved to Z2 and Z4 transmission substations for random distribution daily each day. In running this programme the system software used for the development of the system includes; Java Development Kit (JDK), which is an environment for developing java application and Net Beans 8.2 which is the Java Development Environment platform used for text editing, debugging and testing. The runtime environment is Java Run Time Environment (JRE) version 1.5 which is minimum JRE required for the system to function and an antivirus to protect the system against Trojan and other forms of virus. The hardware minimum requirements are the Processor 1.8GHz (gigahertz) speed or more, monitor with 32bit screen resolution or more and memory of 512MB-RAM (megabyte), 60MB-HDD (hard drive) or more. Figure 2 shows result of energy generated for distribution.

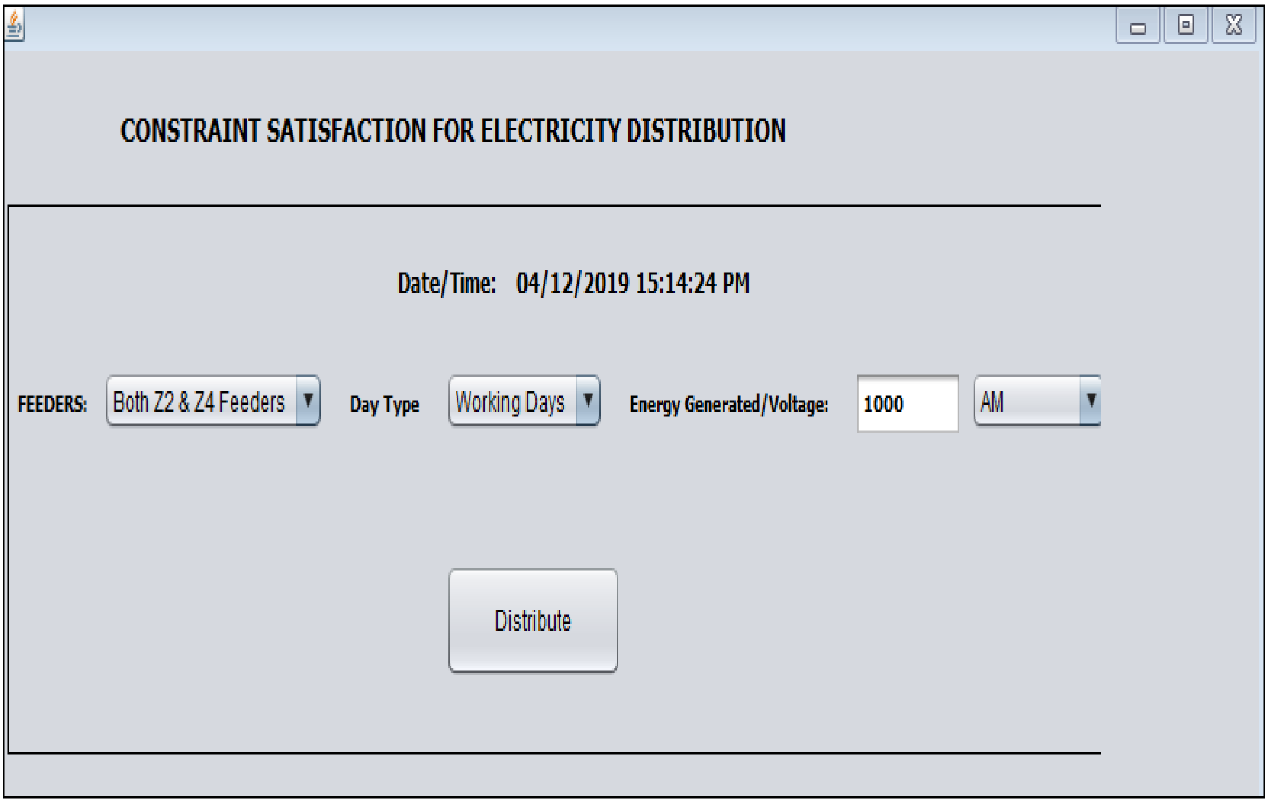

Figure 2. Energy generated/Voltage distribution

The distribution output shown in fig. 2 shows how electricity is distributed to the different areas under Z2 and Z4 feeders, including the allocation to the different distribution areas with generated voltage of 1000 distribution to each areas, with hours of allocation and voltage consumption by each area during working hours of the day. Fig 3 shows how electricity is distributed to the different areas applying Bayesian network for optimal distribution, therefore, lower voltage of 11% for residential areas will be distributed during working hours of the day, average of 30% to commercial areas will be distributed during working hours of the day, and 59% to critical areas during distribution. The rational for the above distribution is based on need and effective maximization of available energy to the three areas under consideration made possible by applying Bayesian network. See figure three below:

Scientia Africana, Vol. 18 (No. 2), August, 2019. Pp 91-100
© Faculty of Science, University of Port Harcourt, Printed in Nigeria ISSN 1118 – 1931

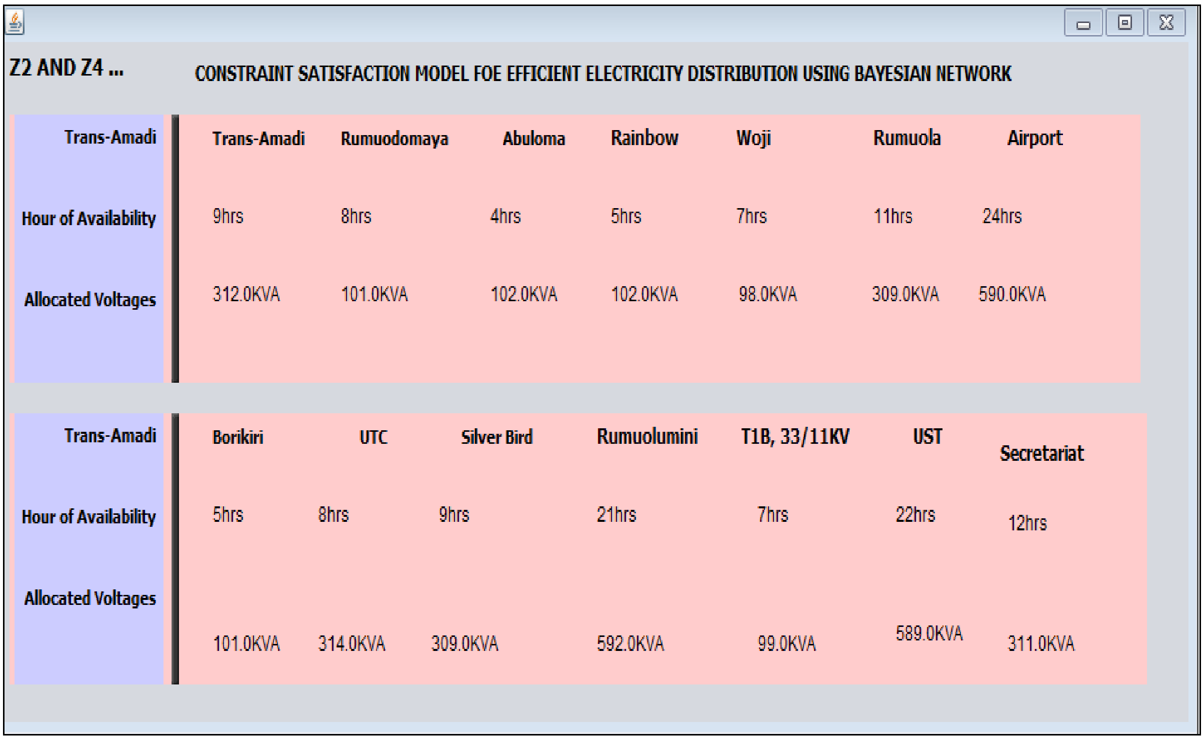

Figure 3: Distribution to Z2 and Z4 area

The distribution result in table 1 shows electricity distributed to the different areas in Z2 and Z4 feeders. Table 1 gives details of the areas and their descriptions, voltage and time allocated are shown below:

Table I Showing area, allocated time, and distribution voltage to Z2 and Z4

Distribution table for Z2 and Z4			
Area	***Allocation time***	***Allocated voltage***	***Area description***
Trans amadi	*9hrs*	*312.0*	*Commercial area*
Rumuodumaya	*8hrs*	*101.0*	*Residential area*
Abuloma	*4hrs*	*102.0*	*Residential area*
Rainbow	*5hrs*	*102.0*	*Residential area*
Woji	*7hrs*	*98.0*	*Residential area*
Rumuola	*11hrs*	*309.0*	*Commercial area*
Airport	*24hrs*	*590.0*	*Critical area*
Borokiri	*5hrs*	*101.0*	*Residential area*
UTC	*8hrs*	*314.0*	*Commercial area*
Silverbird	*9hrs*	*309.0*	*Commercial area*
Rumuolumini	*21hrs*	*589.0*	*Critical area*
TIB	*7hrs*	*99.0*	*Residential area*
UST	*22hrs*	*589.0*	*Critical area*
Secretariat	*12hrs*	*311.0*	*Commercial area*

The outcome result from the table shows Airport, Rumuolumini, and UST are the critical areas with higher number of hours allocated during distribution, these area are called critical because it is essential and very important to have uninterrupted electricity distribution for the successful running of the airlines, schools, hospitals, banks etc. Trans amadi, Rumuola, UTC, Silver bird, and Secretariat are commercial areas receiving average distribution of energy allocation. The commercial area is a description of business centers where people carry out their day to day businesses, while, Abuloma, Woji, Rumuodumaya, Rainbow, Borokiri, TIB are residential areas with lower hours of electricity distribution during working hours of the day. The area residential as named is where people reside or retire back to at the close of work. The distribution graph is shown in fig 4.

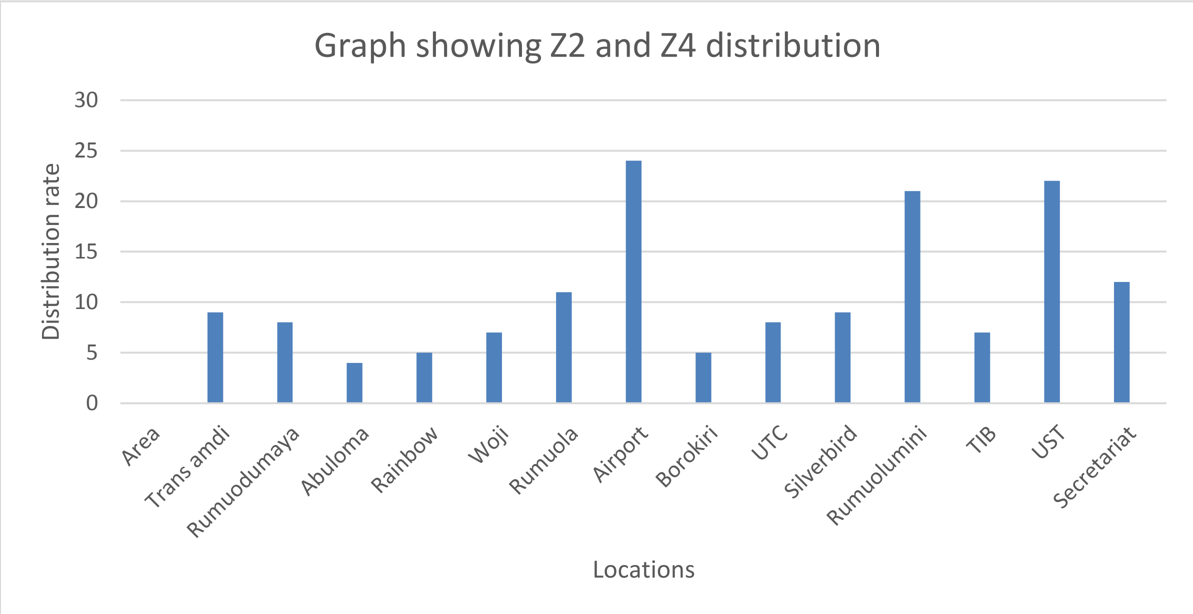

Figure 4. Distribution graph for Z2 and Z4 area

The aim of this work is to generate and distribute electricity in Port Harcourt main (Z2) and Port Harcourt town (Z4) feeders optimally despite the constraint in energy received daily. The three distribution areas looked at in this work are the critical areas, commercial areas, and the residential areas. The system is meant to distribute the amount of voltage received daily with higher voltage of 59% generation to critical areas during each day of the week and also on weekends because of their importance. While average voltage of 30% electricity received is distributed to commercial areas during working hours of the day, this is followed by residential areas which receives lower voltage of 11% during working hours of the day. But on weekends and evening the system automatically, distributes average load of 30% to residential areas and 11% of voltage received to commercial area.

CONCLUSION

Findings reveal that energy generated voltage received and distribution to

Scientia Africana, Vol. 18 (No. 2), August, 2019. Pp 91-100
© Faculty of Science, University of Port Harcourt, Printed in Nigeria *ISSN 1118 – 1931*

different areas in Z2 and Z4 feeders were optimally distributed. The different areas mentioned and schedule structures on distribution were clearly stated. Energy voltage of 1000 Kilovolts was applied for distribution during working hours to the different areas and the distribution result shows priority were given to each area according to their scheduled structure. The research findings ensured that Port Harcourt City enjoys adequate and effective electricity supply using Bayesian network. Distribution of electricity to critical, commercial, and residential areas is automated to reduce waste and ensure efficiency of electricity supply to all distribution areas. A system software that was used to efficiently distribute voltage across different areas such as critical, residential and commercial areas was built in resolving the issues of distribution. Constrain satisfaction model was applied and found to be better and more efficient than the existing system in use by electricity distribution sector. This work has revealed distribution pattern for efficient electricity distribution in Port Harcourt main (Z2) and Port Harcourt town (Z4). Further research should be made on the advancement of satisfaction schedule structure which discourages interruption of energy distribution through efficient direct distribution and adequate schedule pattern that reduces constraints and increase supply of electricity applying constraint satisfaction model.

REFERENCES

Bartak. R. (1999). *Constraint Programming: In Pursuit of the Holy Grail. Vol. 4,* pp. 555-564.

Bian, Z., Chudak, F., Israel, B. R., Lackey, B., Macready, W. G., Roy, A. (2016). Mapping constrained optimization problems to quantum annealing with application to fault diagnosis, *arXiv preprint arXiv: 1603.03111, 2016*

Crnkovic, G. D. (2010) *Constructive research and info-computational knowledge generation*. Volume 314, pp. 359-380.

Diawuo, F. A., and Kaminski, J. (2017). An analysis of Ghanaian power generation sector using an optimization model. *Journal* 97(1), 2017

El-Taweel, N. A. and Farag, H.E.Z. (2017) A distributed constraint satisfaction approach for active power sharing in microgrids. *Electric Power Research Article. 147: 42-54.*

Hu, Q. Huang, G. H., Cai, Y., and Sun, W. (2014) Planning of electric power generation systems under multiple uncertainties and constraint-violation level. *Article 23(1):55-64*

Kruchten, P. B. (1995). The 4+ 1 view model of architecture. *IEEE software,* 12(6), 42-50.

Li, H., Liang, Y., Zhang, N., Guo, J., Xu, D., and Li, Z. (2016) Improving degree based variable ordering heuristics for solving constraint satisfaction problem. *Journal of Heuristics, 22(2), 125-145.*

Lishinski, A. Yadav, A. Good, J., and Enbody, R.J. (2016) Learning to program: Gender differences and interactive effects of students' motivation, goals, and self-efficacy on performance. Proceeding of ACM Conference on International

Computing Education Research, pp. 211-220

Mekni, M., Buddhavarapu, G., Chinthapatla, S., and Gangula, M. (2018) Software architectural design in agile environment. *Journal of Computer and Communications 6(01), 171-189.*

Mahmoud, A. S., Sanni-Anibre, M. O., Hasanain, M.A.W. (2019). Key performance indicators for the evaluation of academic and research laboratory facilities. *International journal of building, pathology and adaptation 37 (2), 208-230, 2019.*

Montanari, U. (1974). Networks of constraints: Fundamental properties and applications to picture processing. *Article in information science 7:95-132*

Oyegoke, A. (2011). The constructive research approach in project management research. *International Journal of Managing Projects in Business 4:573-595*.

Powell-Morse, A. (2017). *Ruby exception handling: Local jump error. 535* Mission Street, 14th floor, San Francisco, CA *94105*

Quach, X. H. & Hoang, T.L.G. (2017). Dealing with fuzzy ontology integration problem by using constraint satisfaction problem. *Article of Advanced Compute Research 7(30), 81-87.*

Wang, P., Wang, C., Hu, Y., Varga, L. & Wang, W. (2018). Power generation expansion optimization model considering multi-scenario electricity demand constraints: A case study of Zhejiang Province, China. *Energies. 11 (6), 1498, 2018.*