Adoption of Smart Grid in Ghana Using Pattern Recognition Neural Networks

Conference Paper · March 2019

DOI: 10.1109/ICCMA.2019.00018

7 authors, including:

Ruhiya Abubakar
Ghana Communication Technology University
16 PUBLICATIONS **31** CITATIONS
SEE PROFILE

Emmanuel Effah
Ghana Communication Technology University
2 PUBLICATIONS **4** CITATIONS
SEE PROFILE

Samuel Akwasi Frimpong
Ghana Communication Technology University
6 PUBLICATIONS **16** CITATIONS
SEE PROFILE

Amevi Acakpovi
Accra Technical University
99 PUBLICATIONS **415** CITATIONS
SEE PROFILE

Adoption of Smart Grid in Ghana Using Pattern Recognition Neural Networks

Ruhiya Abubakar[1]
Faculty Of Engineering/ Department Of Electrical And Electronics Engi.
Ghana Technology University College/PhD Scholar Of Ramaiah University Of Applied Sciences
Ghana/India
rabubakar@gtuc.edu.gh

Emmanuel K. Effah[2]
Faculty of Engineering/ Department Of Electrical and Electronics Engi.
Ghana Technology University College
Ghana
eeffah@gtuc.edu.gh

Samuel Akwasi Frimpong[3]
Faculty of Engineering/ Department of Computer Engineering
Ghana Technology University College
Ghana
sfrimpong@gtuc.edu.gh

Amevi Acakpovi[4]
Department Of Electrical Engineering
Accra Technical University
Ghana
acakpovia@gmail.com

Patrick acheampong[5]
Faculty of Computing and Information Technology
Ghana Technology University College
Ghana
pacheampong@gtuc.edu.gh

Govind R. Kadambi[4, 5]
Department of Computer Engineering M.S. Ramaiah School of Advanced Studies, Bangalore
govind@msrsas.org

K.M Sharath Kumar[4, 5]
Department of Management Studies, M. S. Ramaiah School of Advanced Studies, Bangalore,
dd.sr@msruas.ac.in

ABSTRACT

Deployment of Smart Grid is neither a goal nor a destination, but rather an enabler to the provision of reliable, secured and clean electricity for the end- user or consumer. Overall Smart Grid vision is very well explained with the future of electricity systems, which largely depends on digitization and automation of the overall electricity value-chain, by enhancing electric power information to bi-directional flow and the provision of services that can support the operations of the generation, distribution and end-user usage of power can lead to improvement of electric power system efficiency.

This work aims at analyzing factors and forecast effects on the adoption of Smart Grid in Ghana using Pattern Recognition Neural Net. The Primary data was collected using structured questionnaire and the questions were designed to test the perception of consumers on the deployment of Smart Grid. Also, the target group of respondents covered 80% of the regions in Ghana. Based on the collected data, the pattern recognition neural networks was employed in the analysis of data. Results indicated that education, government policy, cost and safety were the main drivers to the deployment of Smart Grid in Ghana. Other drivers like culture and societal perception recorded as insignificant variables to the deployment of distributed generation in Ghana. It is recommended that further research work should examine the extent of infrastructural preparedness of Ghana for the deployment of Smart Grid.

Keywords—Smart Grid, Pattern Recognition, Neural Network, forecast, adoption.

1. INTRODUCTION

There has been a rise in digitalization of energy systems globally and Utility companies are facing challenges in the generation, transmission and distribution of electric energy, leading to revenue losses due to grid defection as well as net metering systems [1].
This situation is not different in Ghana due to the challenges in the deployment of Smart Grid (SG) and renewable energy even though it outpaces other energy forms compared to fossil fuel prices sky-rocketing [2], in effect affecting global economic growth by making it remain stagnant [1] which could be rescued by integrating Smart Grid to the archaic traditional electricity system.
According to the U.S, Department of Energy (DOE), *Smart Grid is referred to as "an intelligent electricity grid that makes use of digital communications and information technology or distributed generation systems for automatic monitoring, detection and reaction to defects in systems and local changes in the usage of electrical energy.* The goal of SM is to improve on system operating efficiency of system and reduction in system operating costs, while maintaining reliability, stability as well as resilience in the system" [3][11].
The international trade administration [1] places Ghana at 42nd in the rankings of the drivers and the deployment of grid modernization equipment available in 2017, considering narrowing the ranking to the best West African country in the Smart Grid ranking conducted, Nigeria was placed 31st and thus more work needs to be carried out in the area of deployment and the integration of Smart Grid in Ghana. Moreover, the use of Distributed Grid will be a paradigm shift by spreading the small power generation plants into grids for consumption instead, of transmission from long distances which is accompanied by losses and increased cost of supply of electrical energy and consequently increasing supply to demand balance gap. A typical example is an impact study of relocated a generation plant in Kumasi-Ghana to improve the reliability and reduced transmission losses, which

978-1-7281-0818-6/19/$31.00 ©2019 IEEE
DOI 10.1109/ICCMA.2019.00018

usually happened due to long distant transmission from Accra-Ghana [26].

In 2016. [3], Matallanas, proposed an Active Demand Side Management (ADSM) algorithm to improve the efficiency of Smart Grid by using Artificial Neural Networks (ANN). This strategy was applied locally but its effect was realized globally and so the need to include customers and consumers of electricity in the planning stages of the integration in Smart Grid to attain smooth deployment and efficiency [Matallanas (2016)]. Hence there is the necessity to study the perception of consumers on Smart Grid and the barriers to the acceptance and deployments of Smart Grid system in Ghana by employing ANN.

Park *et al.* (2017) and Acakpovi (2019) reviewed the need to consider consumer acceptance as contributing factors that make smart grid business effective. Whilst Park *et.al* (2017) approached it by the application of causal map in order to identify the presents feedback loop among the variables that affect smart grid acceptance. The dynamic changes of the system is shown by a feedback loops, thus reviewing the dynamics of the acceptance of smart grid by mapping the causal maps of the process. Additionally, the combination of the causal maps and stock-flow diagrams were used for analyzing the dynamics of the system. This study was quantitative, thus the magnitude of effects between variables was difficult to observe and so in order to address this issue the stock-flow diagram was applied to determine the influential magnitude of a relationship between the variables, which was performed by entering a function for each relationship [10].

Further, Acakpovi *et.al* (2019), tackled the same issues with the adoption of smart grid technology in Ghana by applying Smart Partial Least Square model (PLS) model for the factor analysis of effects of the adoption on Smart Grid. Results showed that education, cost and governments policy were key variables that influence the integration of SG in Ghana based on the outer and inner loadings and discriminant validity values of these factors were also carried out [9]. Based on literature the fact that active participation of the consumer is needed in SG success [4-5], the efficient functionality of SG depends on participation collaborative and involvements of different stakeholders to the integration and adoption of new technologies, regulations and business models [6-7] for the overall success. Furthermore, studies have emphasized that it is important to include consumers as energy co-providers on electricity consumption in SG systems [8], thus making the consumer' s role matter in the quest to smoothly integrate SG in Ghana, the desire for a sustainable future derived from the prospects and rewards of smart grid in Ghana. Owing to these facts, the need for consumers' behavioural analysis and the need to investigate the effects of latent variables on the adoption of smart grid is on high demand and necessary.

According to Abubakar *et.al.* (2018), on analysis of the inadequacies in existing practices and factors affecting domestic energy demand in Ghana, indicated that, most consumers do not have an idea of smart grid and its benefits. Neural networks has for some decades now been applied for perception measurements and analysis, long and short-term forecast of electricity and electric energy/load demand and supply [12] as well as smart grid challenges and prospects in Ghana. Addressing the key variables and effects of the adoption of SG is the most desired mandate and that can be handled by neural networks model as well, considering its wide usage and application and overwhelming functionality and tools for analyzing perception-oriented variables with direct computation through machines [13].

1.2 Smart Grid

In Ghana, the traditional and archaic system of electric power generation and supply to consumers is drastically approaching its limitations due to the inadequacies in demand caused by factors such, population, over reliance on fossil fuel, rural urban migration, infrastructural inadequacies etc. [12] As a result, both customers and suppliers are not satisfied with the services rendered by utility companies due to the poor visibility of information and lack of situation awareness of the electric power system, which could be resolved by applying Smart Grid Technology to improve on real-time information transfer as well as reliable and customer pro-active decision for demand and supply balance [12][21].

Failures in energy security can lead to several other catastrophic cause by the level of risk in both the grid components as well as the consumer and thus the need for a reliable and secure electric power systems where information can be transferred in both ways or bi-directional and not the uni-directional way of communication practiced traditionally [21].

According to the U.S, Department of Energy (DOE), Smart Grid is referred to as "an intelligent electricity grid that makes use of digital communications and information technology or distributed generation systems for automatic monitoring, detection and reaction to defects in systems and local changes in the usage of electrical energy to facilitate two-way information flow for electric power demand and supply attainment. Mainly the goal of this is to improve on system operating efficiency and an overall reduction in system operating costs, whiles maintaining reliability, stability as well as resilience in the system" [3][11].

SG is not the destination of the fight of greatness in power systems but rather a motivational platform for the attainment of its numerous merits and thus the foundation to the achievements of the uncountable advantages it comes with [22]. Apparently, this is a collective effort from generation, distribution functionalities and choice of electrical appliances by the end user as whole unit [23]. Figure 1 illustrates the Smart Grid reference architecture. Where, the interoperability layers, domains and zones are clearly defined for sustainable future.

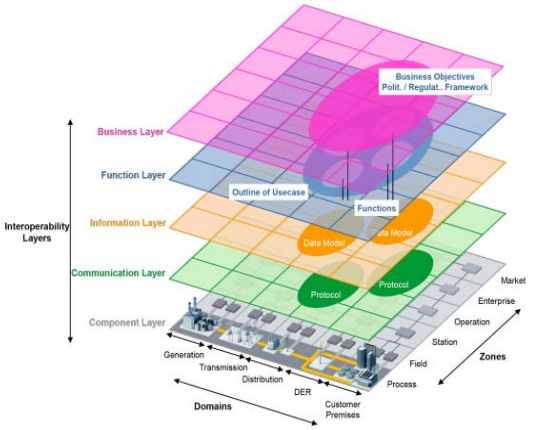

Figure 1: Smart Grid Reference Architectural Model (SGRAM) [20]

2.0 **Related Works**

In recent years, Modern electric power systems have been greatly expanded and evolved by massive integration of Active Distribution Networks(ADN) Distributed Generation (DG) and Multi-Energy System (MES) with an over association of active customer participation in the system[14], [15].

Chen *et.al*. (2018) reported in the paper entitled "*learning-based data analytics: moving towards transparent power grids"* by giving an overview and general ideas of current issues and developments in the area of supervised and unsupervised learning models along with data analysis of power system applications. Here, features and concepts of transparent power grids and closed loops of data and knowledge demonstration to extend the methods that apply data in order to retrieve knowledge in the transparent power grids [16]. Consequently, the more an electric power is transparent in data presentation, the better the knowledge sharing ability, thus the more consumers and utility companies understand the systems. Being educated on the features of transparent electric power system has a great tendency of improving on the reliability and confidentiality of data by consumer and reduce their resilience to the deployment and acceptance of the system.

Once an electric power system is transparent in data analysis the future to the attainment of SG beneficial attributes is close and so the next step to tackle will have to deal with the wireless transmission and distribution of the data at a reduced failure and less error rate by an improve monitoring of data transfers for reliable services, in solving this, several wireless network technologies are recommended based on their abilities and correctness. This is in the roadmap of the SG interoperability standards [18, 19]. This aspect of the information communication technology of SG was analyzed by Zahurul *et.al* (2016), where several wireless communication technologies were compared by looking at their protocols, standards, topologies, as well as their merits and demerits as far as SG is concerned to identify and facilitate the optimization of network solution to integrate DRG to the future SG in Malaysia. Results indicated that, ZIGBEE technology was recommended for the TND SG plan at the distribution end due to its low power and low data rate ability. To address this, the use of optical fiber-backbone was suggested to support theZigBee PRO network for reducing interferences, and additional infrastructural cost [17].

Acakpovi *et.al* (2019), also researched on the factors analysis of main drivers that affects the adoption of Smart Grid technology in Ghana by applying Smart Partial Least Square model, choosing Smart PLS for this work was because of latent variables involve as the divers and variables to measure due to the target group, in this case consumers. The deployment of SG comes with lots of prospects and education and governments policies will greatly influence it integration, whereas the aspect of cost also influences its acceptance from the consumer perspective.

Another empirical study was one conducted in Ghana came by Akom *et al.* (2018) who sought to examine the use of SG technology to integrate Renewable Energy Resources (RES) into the Ghana's power generation sector. The paper identified series of challenges that continue to derail the implementation of Smart Grid in Ghana's energy sector. Some of the challenges included ineffective power generation, outdated transmission and distribution systems, outdated metering methods. The researcher emphasized that Smart Grid was the way to go if the Country want to generate enough power and offer a more efficient transmission as well as distribution. The paper commented on how SG has transformed some developed countries and as a result can transform the energy/electricity sector of Ghana in a similar way. Thus, it was echoed that the fact that smart grid technology with all its benefits are adopted, the current shortfalls in Ghana's energy sector could be minimized and penetration to the entire country will become a reality. A key limitation of this research work is the fact that no empirical data was collected and analyzed as to whether adoption be favored [24], however this current study seeks to test with data the adoption of smart grid in Ghana.

Zaglago *et al*. (2013) consider barriers affecting the adoption of smart grid from the professional (industry) point of view. It outlined several barriers and the topmost was lack of capital, in that it has the potential to invigorate large implementation of efficient energy technology (SG) [25]. Other diming barriers included high levels of political and financial risk, inconsistent and punitive tax regimes, government energy-price subsidies, closed domestic markets, high cost of electricity generation, low emissions fines, and lack of market and management training. It also reiterated the need to encourage consumer education as consumer education was another way of harnessing the full potential of smart grid. Their approach to adoption was based on industrial approach without considering much from users' perspective.

Even though numerous works in the deploying and acceptance of SG has conducted. None has applied the neural network model on pattern recognition to analyze the effect of these factors that affect Smart Grid.

2.1 Pattern Recognition Neural Network

The act of recognizing patterns from statistical extracted data or a classification based on knowledge pre- gained, using machine learning algorithm is referred to as Pattern Recognition Neural Network. Here, the entire dataset is segmented into two parts, one part which is usually the greater percentage of the dataset used in training the model and referred to as the Training data set while the lower percentage part is used in validating and testing the model after training. Pattern recognition of neural networks is rarely applied in the electric power area. Thus, applying it in the research work is to validate the results obtained in other studies such as one conducted by Acakpovi *et.al* (2019), in order to endorse on the assertions of the results and conclusion drawn in this regard.

3.0 Methodology

Here, an outline of methods and tools used in the analysis of the dataset acquired by quantitative survey conducted in the Greater Accra region and a target group of end-users of electricity. Reason for choosing the tools and target group was derived from literature and the need to measure the perception of consumers in order to achieve an overall co-partnership and active participation in the deployment of Smart Grid technology in Ghana.

Questionnaire were the main tool for data collection and population size was derived from error limits of the training data test. Pattern Recognition Neural Network model is applied for the analysis of the

variables that affect Smart Grid by considering their weights form the model design to make a pronouncement of the key factors that greatly affect the deployments of SG in Ghana and also forecast to ascertain the behavior of these variables declared as most influential factors for Smart Grid integration, to take future plan and strategic actions.

Structured and closed ended questionnaire was used and questions were targeted at measuring the perception and mind –set of consumers with regards to SG adoption. Both dependent and independents variables were modeled at the effects of cost, societal perception, education, Government policy as well cultural effects on the deployment of SG in Ghana.

4.0 Data Analysis, Results and Discussions

This section seeks to identify the respective weights that each input parameter has on the adoption of Smart Grids. It also seeks to create a model for predicting the outputs in the given new data. To achieve these, the neural network pattern recognition is selected; particularly, a two – layered feed-forward network with ten sigmoid hidden neurons and one output neuron was formed using the neural network pattern recognition application in MATLAB. The network architecture to confirm the parameters is seen in Fig. 2. The inputs used for training were Education (1) , Government Policy(2) , Culture(3), Societal Perception(4), Safety (5) and cost(6) and the output was on the adoption of Smart Grid. Seventy percent of the data (308 samples) was used for training the neural network and thirty percent was used for validation and testing the network.

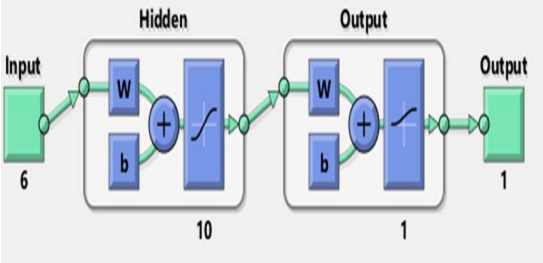

FIGURE 2 : SCHEMATIC DIAGRAM OF NEURAL NETWORK

Table 1 also addresses one of the objectives of this paper which is to identify the relative importance of the various factors that influence the adoption of smart grid. The values were derived from the weights of the neural network and the connection weight (CW) algorithm in [27] given by, $RI_x = \sum_{y=1} W_{xy} W_{y}$. RI_x refers to the relative importance of input neuron x, $\sum_{y=1} W_{xy} W_{y}$ is the sum of product of the final weights of the connection from the input neuron to the hidden neurons with the connection from the hidden neurons to the output neuron. It is worthy to note that irrespective of the number of times the data set is trained, the outcome of the effect of the variables on the deployment of smart grids remains the same. From the table, education has the greatest impact on the adoption of smart grid with the least being societal perception.

Table 1: Weighting of the effects of Adoption Smart Grid

Factors affecting adoption of SG	Edu.	Gov.t Policy	Culture	Societal Perception	Safety	Cost
Connection Weights	10.86	2.60	-1.16	-4.21	1.71	2.37
Rank	1	2	5	6	4	3

Figures 3 to Figure 5 show the accuracy of the model during training, validation and testing steps. Specifically, the confusion matrix in Figure 3, shows that the overall network outputs were very accurate in predicting the targets. This is evident in the green coloured value (91.4%) found in the lower right deep grey square. The network was also more accurate (76.4%) in determining the adoption class (1) rather than identifying responses which were not for the adoption of smart grid class (0). These values are found in the diagonal green coloured squares.

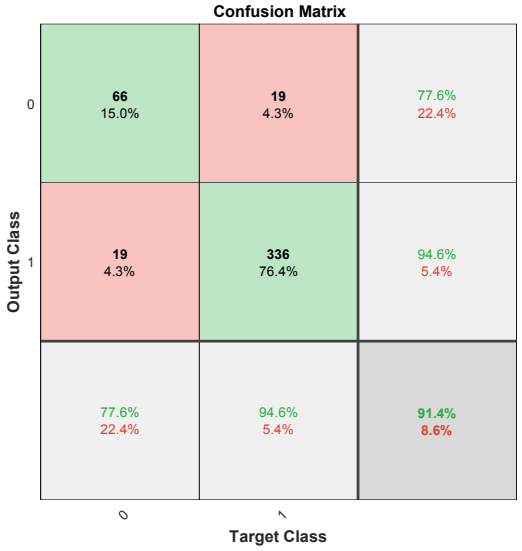

Figure 3: Overall Confusion Matrix

The error histogram show that the network errors are distributed at a reasonably good range around zero although it is skewed to error values of 0.064 and 0.159. The best validation performance was recorded as 0.38. The overall mean average value (performance) for the network was recorded as 0.2844. While it is desirable to attain values tending to zero, it is also important to prevent overfitting. The recorded error is therefore well posed for the purpose of classification.

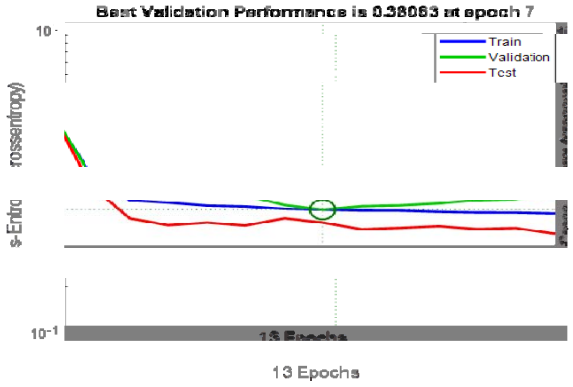

Figure 4: cross entropy error

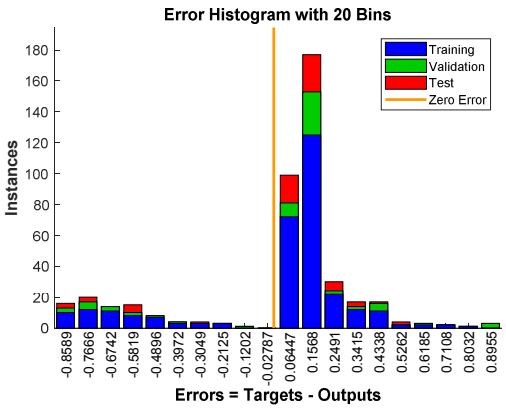

FIGURE 5: ERROR HISTOGRAM OF MODELLED NETWORK

5 CONCLUSION AND RECOMMENDATION

The aim of the research is to analyze the factors that affect the adoption of smart grid in Ghana and to forecast these effects for future planning and development was duly achieved. Results obtained using pattern recognition neural network through a MATLAB curve fitting tool indicate that the main variables that affects the adoption of smart grid which include cost, education, societal perception, Government policy, culture and safety were analyzed by considering the weights of various variables under test for factor analysis. Here, education, Government policy, cost and safety in the order of decreasing weights are the factor that greatly influence the adoption of SM.

Clearly, this work has validated the research conducted by Acakpovi *et al*. (2019), [9] where Smart PLS tool was applied for the factor analysis of the dependent and independent variables on the adoption of Smart Grid in Ghana. In their work, the key variables that affects the adoption of Smart Grid were education, cost and Government policy in that order, which is the same as the results obtained by applying pattern recognition neural networks. Furthermore, this work was able to indicate the forecasting ability of the model dependent on the input data. Hence, the model is able to predict and determine if an input dataset is against or for Smart Grid integration. Conclusively, the effects of the adoption of Smart Grid in Ghana is highly dependent on the education, government policy, Cost and safety, thus with an increase in Smart Grid education to consumers, improved Government policy to be in line with the Smart Grid integration and development policies and also subsidizing the cost Smart Grid adoption comes with and finally making it safe for consumers to access information and play the bi-directional information flow activities safely are improve on the adoption process of Smart Grid.

REFERENCES

[1]. Smart Grid Top Market Report, Update January 2017, A Market Assessment tool for us exporters, U.S. Department of Commerce, International Trade Administration, Industry & Analysis

[2]. Energy Commission of Ghana (2018) Energy (Supply And Demand) Outlook for Ghana, April 2018.

[3]. Eduardor Matallanas De Avila (2016), artificial recurrent neural networks for the distributed control of electrical grids for photovoltaic electricity

[4] Vukojevic, A.; Miloševi´c, B. (2010) Utilities of future. In Proceedings of the 2010 IEEE International Conference on Sustainable Energy Technologies (ICSET), Kandy, Sri Lanka, 6–9 December 2010; pp. 1–6

[5]. Verbong, G.P.J. Beemsterboer, S.and Sengers, F. (2013), Smart grids or smart users? Involving users in developing a low carbon electricity economy. *Energy Policy* **2013**, *52*, 117–125.

[6]. Samad, T.and Kiliccote, S. (2011), Smart grid technologies and applications for the industrial sector. *Comput. Chem. Eng.* **2012**, *47*, 76–84.

[7]. Heiskanen, E. and Matschoss, K. (2011), Exploring emerging customer needs for smart grid applications. In Proceedings of the 2011 2nd IEEE PES International Conference and Exhibition on Innovative Smart Grid Technologies (ISGT Europe), Manchester, UK, 5–7 December 2011; pp. 1–7.

[8]. Geelen, D., Reinders, A. and Keyson, D. (2013), Empowering the end-user in smart grids: Recommendations for the design of products and services. *Energy Policy* **2013**, *61*, 151–161

[9]. Amevi Acakpovia, Ruhiya Abubakar, Nana Yaw Asaberec, Issah B. Majeed [2019], Barriers and Prospects of Smart Grid Adoption in Ghana, International Conference on Sustainable Materials Processing and Manufacturing, SMPM 2019, Sun City Resort, South Africa, 08 – 10 March 2019.

[10]. Chankook Parka, Hyunjae Kima, Taeseok Yongb (2017), Dynamic characteristics of smart grid technology acceptance, International Scientific Conference "Environmental and Climate Technologies", CONECT 2017, 10–12 May 2017, Riga, Latvia

[11]. Zhang Zhen. Smart Grid in America and Europe: Similar Desires, Different Approaches. Public Utilities Fortnightly, 149, 1, 2011

[12]. Analysis of the Inadequacies in Existing Practices and Factors Affecting Domestic Energy Demand in Ghana, Ruhiya Abubakar, Prof. S.R Shankapul, Dr. Amevi Acakpovi, Ussif William, Patrick Acheampong, International Journal Of Applied Engineering Research (2018)13 (19), 14323-14333

[13]. John Peter Jesan (2004), the neural approach to pattern recognition, Ubiquity, Volume 2004 Issue April

[14]. S. Chowdhury and P. Crossley, (2009), Microgrids and Active Distribution Networks. Scotland: The Institution of Engineering and Technology, 2009.

[15]. P. Mancarella, (2014), "MES (multi-energy systems): An overview of concepts and evaluation models," Energy, vol. 65, pp. 1–17, 2014.

[16]. Kunjin Chen et al. (2018)Learning-based Data Analytics: Moving Towards Transparent Power Grids, CSEE Journal Of Power And Energy Systems, Vol. 4, No. 1, March 2018

[17]. S. Zahurul, N. Mariun et al. (2016) Future strategic plan analysis for integrating distributed renewable generation to smart grid through wireless sensor network: Malaysia prospect

[18]. Colak I, Bayindir R. et.al. (2014), Smart Grid opportunity and applications in Turkey, renew sustain energy Rev.2014; 33:344-52

[19]. Incel OD, Van Hoesel L, Jansen P., Havinga P., MC-LMAC (2011): A Multi-Channel MAC protocol; for wireless sensor networks AD.HOC newt 2011:9:73:94

[20]. S. G. C. CEN-CENELEC-ETSI, "Group (2012)," Smart Grid Reference Architecture, pp. 1–107, 2012

[21]. Yakubu Tsado (2016), Improving the Reliability of Optimised Link State Routing Protocol in Smart Grid's Neighbour Area Network, Doctor of Philosophy thesis, October 2016

[22] Balmert, D. & Petrov, K. (2010, Regulatory Aspects of Smart Metering. ERRA Licensing and Competition Committee-Issue Paper.

[23]. Tsado, Y., Lund, D. & Gamage, K. A. (2015b). Resilient communication for smart grid ubiquitous sensor network: State of the art and prospects for next generation. Computer Communications, 71**,** 34–49.

[24]. Akom Kingsley, Thokozani Shongwe, Meera K. Joseph, [2018], Renewable Energy Integration in Ghana: The Role of Smart Grid Technology 978-1-5386-3060-0/18/ ©2018 IEEE.

[25]. Light. Zaglago, Craig. Chapman, and Hanifa Shah, Member, IAENG [2013], Barriers to Nationwide Adoption of the Smart Grid Technology in Ghana. Proceedings of the World Congress on Engineering 2013 Vol III, WCE 2013, July 3 - 5, 2013, London, U.K. ISBN: 978-988-19252-9-9

[26]. Electricity company of Ghana, 2018 electricity supply plan for the Ghana Power System, a 2018, power supply outlook with medium-term projections. www.energycom.gov.gh/planning/.../energy-outlook-for-ghana?...energy-outlook.

[27]. O. M. Ibrahim (2013), A Comparison Of The Methods For Assessing the relative importance of input variables in artificial neural networks, Journal of applied sciences research, 9(11): 5692-5700, 2013, ISSN 1819-544X

[28]. M. Samadani et al. (2013), diagnostics of a non-linear pendulum using computational intelligence. Preceding of the ASME, 2013. Dynamic systems and control conference.