Renewable Energy Sources and Grid Integration in Ghana: Issues, Challenges and Solutions

K. Akom
Elect./Electronic Eng. Dept
University of Johannesburg
Johannesburg, South Africa
kingsleyakom@yahoo.com

M.K Joseph
IEEE Computer Society
South Africa Chapter Chair
Johannesburg, South Africa
josephmeera@gmail.com

T. Shongwe
Elect./Electronic Eng. Dept.
University of Johannesburg,
Johannesburg, South Africa
tshongwe@uj.ac.za

***Abstract*—Due to the high cost of fuel and as unfavourable weather conditions which have affected power generation in Ghana, the country has experienced power crises for the past seven years. Renewable Energy Resources (RES) like wind and solar are being considered by many countries as alternatives for the energy requirements of the country. Ghana's Energy Commission's (EC) report in October, 2017 indicated that, RE contributes 2MW of power to the country's energy mix, representing about 1.73% of the total installed capacity. However, the current EC's energy policy has projected 600MW power through RE in 2030. 340 MW from solar and 260 MW from wind energies. The then Ministry of Energy through the Energy Commission started the rooftop PV programme implementation in early 2016 in some government institutions. The main aim of the rooftop programme was to produce about 200 MW maximum load respite on the national grid as a medium term programme through PV solar technology. However, RE and grid integration has various issues and challenges, large scale RE power generation are mainly connected to the transmission systems and small scale generation are mostly linked with the distribution system. Direct integration these systems poses a lot challenges and issues. This paper examines the main issues and proposes some probable solutions for future RE generations and integration.**

Keywords – Power Electronic Technology, Renewable energy source, grid integration, generation, transmission, distributed.

I. INTRODUCTION

Usage of RE has gradually become an alternative source of power all over the world, most especially in developed and developing countries due to the fast exhaustion of fossil fuels [1]. The high cost of fuel for various electrical power plants, bad weather conditions and the related environmental challenges. Owing to the intermittent nature of RE sources, its integration into the main grid always leads to issues in both non-technical and technical challenges. To increase the renewable energy contribution in Ghana, the government as at March, 2017 had issued provisional wholesale power supply licenses to some 90 prospective IPPs to produce 5,000 MW of electricity from the RES available in Ghana [2, 3]. 60 out of the licenses issued proposed solar photovoltaic (PV) generation with 3,000 MW capacity of energy supply. 25 of the companies were licensed to produce solar energy with 3 companies issued with solar PV construction project license. 4 companies were issued with Construction Permit on wind energy to produced 225MW power [4].

In an effort to contribute to the national goal of universal access by 2020 and promote socioeconomic development through Productive Use of Energy (PUE), the second phase of the National Rooftop Solar Programme which focuses on providing electricity to rural households in off-grid communities which might not have access to electricity by 2020 and beyond was piloted in 2017. Solar PV systems of 500Wp capacity each were piloted in 200 rural households in 16 off-grid communities in the Abetifi and Mpraeso constituencies of the Eastern Region. Partial funding was secured from the Skills Development Fund (SDF) of COTVET 91 to train 250 technicians for designing, installation and maintenance of the solar PV system. However, ECG put the scheme on hold in the first quarter of 2017 for alleged fear of reduction in their revenue generation. The Energy Commission in collaboration with ECG and PURC are therefore currently working on resolving this challenge [2, 4].

The adoption of solar and wind energy systems has become a major challenge for most utility providers due to the potential negative influence it will pose on the power network operations system [2] . Another challenge on solar and wind energies is the fluctuation and intermittent power supply which has negative impact on the operation of the electric network, feeders [3] and nodes in the power network system [4]. Additionally, the variations and intermittent nature of solar and wind energies do not permit for using them in the process of planning and generation of electricity. The paper will examine all these challenges and provide probable solutions to those issues and challenges.

A. Objective

The main objective is to investigate the Renewable Energy Sources and Grid Integration in Ghana, explore the key issues and suggest some possible solutions.

B. Methodology

The methodology used for the studies are both qualitative and quantitative approach. In all, 42 questionnaires were sampled and analysed. Managers of Ghana's electrical energy systems were contacted and interviewed. They include engineers, technician engineers, technicians and artisans in Electricity Company of Ghana, Ghana Grid Company, Northern Power Distribution Company and some independent power producers.

II. DATA COLLECTED AND ANALYSIS

Two main tools were adopted in this regard, the data was collected through survey questionnaires. Since that was easy and less expensive according to Seliliz [5] than personal interviews. The questionnaires were developed to capture basic and technical all-inclusive data about the current state of energy situation in Ghana. The questionnaires were delivered by hand to each respondent and collected by the researcher. A second questionnaires were designed in a form of semi-structured interviews for the managers of the above mentioned companies in both

close and open questions. Each interview lasted for about 45 minutes [3, 5]. Validity and reliability were ensured in the designing process of the questionnaire [5]. Frequency tables and descriptive statistics were created to display results with respect to each of the research questions. The analysis were than through inspection and checks of the surveys for wholeness and exactness, open coding and inputting data into a database in SPSS, and final execution of the descriptive responses in accordance with the descriptive statistics and frequency distributions.

A. Development and Distribution of Instruments

The questionnaires and the structured interview were developed to collect data for the following.

- The Current State of energy Situation in Ghana
- Renewable Energy projects in Ghana
- Overview of Renewable Energy projects in Ghana.

In arriving at the questionnaires and structured interview used for this work, series of tried ones were developed and given to colleagues and they gave a lot of valuable contributions and all these were incorporated in the questionnaires and structured interview to make sure that they were eliciting the right answers. Structured interview is the type of interview which is planned and written by the researcher. It guides him to look for the appropriate questions required for the interview. The interview was granted to the managers of VRA, ECG, GridCo and IPPs. The researcher went round administering the instrument in order to avoid the incidence of slow return rate. This was not an easy task since it involved extensive traveling across the country within a short time.

B. Quantitative Analysis

Table 1 Current state of energy supply in Ghana

	Frequency	**Percent**
Sufficient	10	18.9
Insufficient	30	56.6
Highly insufficient	13	24.5
Total	**53**	**100.0**

Table 1 shows that the majority (n=30, 56.6%) of the respondents indicated the current state of energy supply in Ghana is insufficient. Additionally, 13 (24.5%) of the respondents think that the current state of Ghana's energy supply is highly insufficient. From the responses, it can be concluded that current level of energy supply in the country is insufficient.

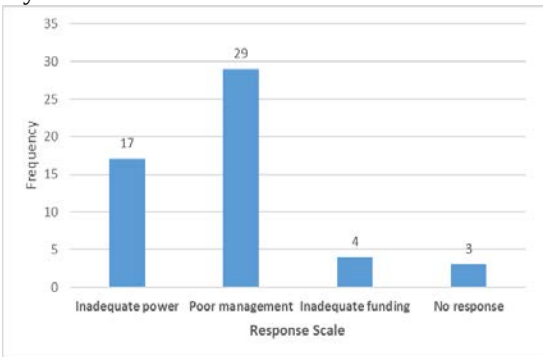

Figure 1 Causes of energy shortfall

Concerning the possible causes of the shortfalls in energy supply, the outcome as shown in figure 1 depicts that just about half (n=29) of the respondents attributed the causes to poor management whereas 17 respondents suggested inadequate power as the main causes of the shortfalls in energy supply in Ghana. The responses imply that mainly, poor management of the energy sector can be blamed for the current state of energy supply in the country.

Table 2 Degree of contribution from independent power producers

	Frequency	**Percent**
High	11	20.8
Moderate	7	13.2
Low	22	41.5
Very low	10	18.9
No response	3	5.7
Total	**53**	**100.0**

Enquiries about the current degree of contributions from independent power producers were made. From the table 2 it could be seen that 22 being 41.5% of the respondents indicated that there is low contribution to the energy supply by the independent power producers. However, 11 (20.8%) of the respondents suggested that they contribute highly to the country's energy supply needs. From the foregoing, it can be concluded that the contributions of the Independent Power Producers (IPPs) in Ghana is low.

Table 3 IPPs role in fixing prices in the energy sector

	Frequency	**Percent**
Very high	10	18.9
High	7	13.2
Moderate	4	7.5
Low	17	32.1
Very low	12	22.6
No response	3	5.7
Total	**53**	**100.0**

The results in table 4 concern the role of the IPPs in fixing prices in the energy sector. The responses suggest that the majority (n=17, 32%) of the respondents stated the producers have low involvement in the fixing of prices in the energy sector. That notwithstanding, 12 representing about 23% of the respondents described it as having very low involvement in the pricing in the energy sector. The responses imply that the IPPs relatively do not play in any significant role in fixing prices in the energy sector. From table 4, descriptive statistics show that Solar obtained the highest mean score of 1.66 (SD=.478) among the other renewable energy resources. Followed up is Geothermal Energy with a mean score of (m=1.13, .342). Furthermore, respondents suggest Wind Energy (m=1.06, SD=.233) and Tidal Power (m=1.06, SD=.001). From the results, it can be concluded that solar energy remains the suitable renewable energy to augment the country's energy supply.

Table 4 Descriptive Statistics on renewable energy resources suitable for Ghana

	No.	Minimum	Maximum	Mean	Std. Deviation
Solar	53	1	2	1.66	.478
Wing Energy	53	1	2	1.06	.233
Geothermal Energy	53	1	2	1.13	.342
Biomass Energy	53	1	1	1.00	.000
Tidal Power	53	1	2	1.06	.233
Biofuel	53	1	1	1.00	.000
Valid N (listwise)	53				

The respondents were further requested to indicate which part of the country is suitable for the designated renewable energy development. Using the Kendall's coefficient of concordance for ranks (W^a) which estimates agreements between 3 or more respondents as they rank some subjects according to a particular characteristic as shown in table 6 it could be observed that the Northern part of Ghana received the highest mean score (m=4.39) hence ranked first as the most suitable place for the renewable energy development. Followed by the Western part (m=2.93) of the country.

Table 5 Regions

Region	Mean Rank
Northern Part	4.39
Southern Part	2.68
Central Part	2.50
Eastern Part	2.50
Western Part	2.93

Kendall's Wa=.508, $\chi 2$=83.268, df=4, Sig=.001

Reference to Kendall's (W^a) statistics in Table 5, the coefficients of concordance represents agreements, where 0 means no agreements at all, and 1 represents perfect agreement. A coefficient of 0.508 represents a moderate degree of agreement. Hence, can be concluded that there was significant agreement among the rankers (W^a=.508, $\chi 2$= (4)83.268, p<.05). Funding an important component required for the effective integration of RES into the grid system. Responses in Figure 2 regarding the funding approach required for the integration shows that respondents (n=31, 58.5%) wants the funding to be borne entirely by the government. However, 8 (15%) wants a partnership between the government as well as the independent power producers.

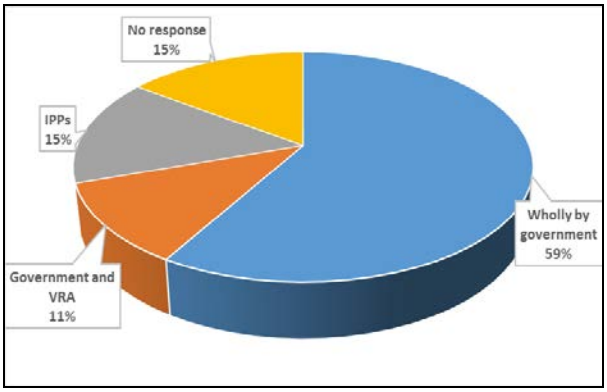

Figure 2 Funding approach required for integrating RES into grid system

From Table 6, responses on the potential of RES to alleviate many challenges facing the power sector suggests that with a mean score of 4.16 majority of the responses were towards the agreement end of the scale giving the impression that investing in the development of renewable energy sector has the inclination to improve the current energy situation in the country. Furthermore, the study showed that again, majority of the responses were around the agreement side of the scale (m=4.24) implying that respondents were in support of the assertion that educational institutions should be encouraged to generate their own power using the renewable energy sector. This means that getting government institutions particularly the educational institutions to develop their own renewable energy sources will lessen the burden on the national grid.

Table 6 Descriptive Statistics

	No.	Minimum	Maximum	Mean	Std. Deviation
RES has the potential to alleviate many challenges facing the power sector	45	3	5	4.16	.673
Educational institutions should be encouraged to generate their own power through RES	45	3	5	4.24	.712
Taxes on RES materials must be removed as a motivating factor	45	2	5	4.11	1.092
Rural Electrification should be solely RES	45	2	5	3.58	1.097

1=Strongly Disagree, 2=Disagree, 3=Not Sure, 4=Agree, 5=Strongly Agree

Additionally, majority of the responses (m=4.11, SD=1.09) gives the impression that the respondents agreed that taxes and duties on RES products should be removed to motivate institutions and individuals to invest in renewable energy sector. Also, regarding rural electrification, the trend of respondents (m=3.58, SD=1.097) suggest that most of the responses were geared towards the agreement end of the scale suggesting that respondents believe rural electrification should solely be on the renewable energy supply. This will help ease the strain on the national grid.

Table 7 IPPs are contributing immensely especially in the Rural areas

	Frequency	Percent
Extremely	11	20.8
Highly	14	26.4
Moderately	17	32.1
Quite/Reasonable	5	9.4
Somewhat	3	5.7
No response	3	5.7
Total	**53**	**100.0**

Assessment of the contribution of the IPPs to the current level of power supply in the country, the results in Table 7 shows that the majority (n=17, 32%) of the respondents view the contributions of the IPPs effort to the current supply of energy in Ghana to be moderate. Additionally, 14 (26.4%) of the respondent's think the IPPs are highly contributing immensely to power supply especially in the rural areas. The outcome of the results gives the impression that the independent power producers are not significantly contributing to the power supply in Ghana.

Table 8 IPPs have greatly influenced the Renewable Energy Sector

	Frequency	Percent
Not at all influential	7	13.2
Slightly influential	8	15.1
Moderately influential	25	47.2
Weak influence	10	18.9
No response	3	5.7
Total	**53**	**100.0**

The respondents were asked to assess the impact of the IPPs are having on the renewable energy sector. The results to that effect in Table 8 shows that the majority (n=25, 47.2%) of the respondents believe the IPPs are moderately influencing the renewable energy sector whereas about 10 (19%) of the respondents described the influence of IPPs in the sector as weak. From the responses it can be concluded that the IPPs are not significantly having much of an impact in the renewable energy sector as expected.

C. Qualitative Analysis

1. Number of Renewable Energy Projects in Ghana

The managers appeared divided regarding the specific number of renewable energy project currently underway in Ghana. However, majority interviewed were of the view that there are about between 4 - 20 renewable energy projects currently taking place in Ghana. Selected responses have been given below;

"We have four renewable energy projects in Ghana…"
"…I can't recollect off-head, but the last time I think it was 15 if my memory serves me right…"
"…There are about 20 separate companies currently in the country working on different renewable energy projects..."

The respondents were further asked to indicate where specifically the projects are located. The responses give the impression that the projects are spread across the country with major projects located specifically at Tema, Takoradi, Navrongo, Kpong and Bui. Some of the responses have been given below;

"Takoradi (Aboadze), Tema, Kpone, Akosombo (Ajena), Bui, Kpong (Akuse), Onyandze and Navrongo…"
"Takoradi, Tema and Accra"

2. Funding of the projects

Concerning sources of funds for the projects, the interview responses revealed the government is the main funding entity of the projects.

"The government is funding the projects with the taxpayer's money…"

3. Current production level of the renewable energy projects

The responses suggest that the perceived 20 renewable energy projects in operation in the country are contributing

between 1.5 to 2.6 MW of power to the nation's energy pool.

4. *Challenges associated with the integration into the National Grid*

From the responses, the majority of the respondents maintained that the main challenge has to do with difficulties in the mode of transmission whereas others also pointed to financial problems. Likewise, there were others who asserted that the risk is concerned with the increasing likelihood of flooding in coastal areas.

> *"It is financial problems that are troubling the projects…"*
> *"…the mode of transmission into the national grid is now the major headache…"*

5. *Use of clouds for integration of renewable energy*

Respondents were requested to indicate whether they consider the use of clouds as an alternative solution to the integration of renewable energy into the system. The majority of the respondents pointed out they are not considering the use of the resource as a means of integration into the system. Some of the responses to that effect have been outlined below;

"No! at the moment that is not what we are looking at…"
"To the best of my knowledge. NO! "No! not at all. No please"

III. ISSUES AND CHALLENGES OF RES GRID INTEGRATION

The main issues and challenges of RE and grid integration are classified in two forms. As a results of the interviews conducted in the study, technical and non-technical issues were emerged as the challenges [6].

A. Technical Issues

Some technical issues confronting the RES grid integration in Ghana are described as follows:

1. Poor Power Quality

The power quality is very poor in terms of harmonics, frequency and voltage fluctuations in various power stations in the country, especially Northern Electrification Distribution Company (NEDCo) Ltd

2. Transmission system

Less availability of transmission line to accommodate RES and the mode of RES transmission in Ghana is very challenging since they are mostly generated and transmitted in single phase.

3. Storage system

Due to the dynamic and complex nature of Power Storage and Grid Solutions**,** coupled with increasing renewable energy installations contributing power to an aging infrastructure in Ghana, energy storage has become an important focus [7, 8]. The study shows that energy storage in Ghana still remain a challenge in terms of frequency regulation and demand charge reduction or peak shaving.

4. Optimal placement of RES

Integration of large scale distribution generation can be limited by these voltage variations in RES [9]. Limited amount of energy storage might not have the desired influence it is also not possible to install large amount of energy storage as this would increase the costs significantly. Therefore it is required to optimally place and size energy storage.

B. NON-TECHNICAL ISSUES

1. Lack of technical skilled man power

Ghana lacks technical skilled man power in the energy sector. The sector also is saddled with huge debt which has affected the remuneration of its employers which attract the most suitable personnel. The government also has placed a ban on employment, so the managers are unable to employ qualify personnel for the sector [2, 3].

2. Poor management

Poor management also affects the operations of the energy sector. The sector is so politicized that, governments appoint the politicians instead of technocrats to manage the sector [3].

3. No Government support for the IPPs

Currently the IPPs lack resources to produce energy as expected of them and the government is not also position to assist in that direction. Successive governments have only shown interest in thermal power generation [3].

C. PROBABLE SOLUTIONS

In most developed countries all over the world solar and wind energy have become alternative energy sources [10] which Ghana must as well considering RES and distributed generators need new approaches for their operations in order to attain reliable and quality power supply [11]. The following propositions have been drawn as probable remedies for the integration of RES and grid systems in Ghana.

1. Minimized power fluctuations and intermittence in RES

The major challenge facing RES is power fluctuation and intermittence in power generation. This can be minimized to the barest minimum by distributing the RE in small units to large topographical areas by focusing on one area at a time [9]. The large solar PV system output power with high rating can be converted within ten minutes to avoid fluctuation and intermittence by natural weather conditions. Fluctuating and intermittence again can be reduced by using them for domestic activities [12].

2. Application of Power Electronic Technology

Power Electronic Technology (PET) is one of the contemporary technologies for distributing energy generated for the renewables and integrate them into the national grid system [13]. This mechanism is extensively applied globally as more efficient way of integrating RE into national grid system and ensuring reliable power with avoidance of fluctuation and intermittence. PET only requires semiconductor changers that have capacity for controlling higher voltages and for switching very fast without delay.

3. Appropriate Storage System is needed

Power output in large solar PV plants continuously fluctuate during the day time and this raises security concerns as fluctuating power results to unstable grid [14]. To resolve grid instability due to power fluctuation, solar PV plant owners will have to install storage systems, this leads to additional cost to installation or operational cost. [15].

4. The use of RES

RES are best utilized when the power is generated and use at the same time. For irrigation purposes, it is always advisable to feed the load at night or off-peak period through conventional grid.

IV. CONCLUSION

This paper, investigated the specific challenges associated with grid integration of RES and appropriate recommendation are made based on observed data results after subjecting the data to a rigorous data analysis. The Northern part of Ghana received the highest mean score (m=4.39) hence ranked first as the most suitable place for the RE development in Ghana. To abate the electric power instabilities and its sporadic problems, power electronics devices were advised as the workable options. From the responses it can be concluded that the IPPs are not significantly having much of an impact in the renewable energy sector as expected. However, solar energy remains the suitable renewable energy to augment the country's energy supply. The application of dump load and proper storage of RE can also reduce drastically fluctuations and intermittence of solar PV systems [16, 17]. RE and grid integration in Ghana is possible and this can help the country to improve on its energy situation.

V. REFERENCES

[1]. T. Ito, H. Miyata, M. Taniguchi, T. Aihara, N. Uchiyama, and H. Konishi, "Harmonic current reduction control for grid-connected PV generation systems", *International Power Electronics Conference*, Brighton, UK. pp 1695-1700, April, 2010.

[2]. A. S. Anees. "Grid integration of renewable energy sources: Challenges, issues and possible solutions", IEEE 5th India *International Conference on Power Electronics* (IICPE), August, 2012.

[3]. L. Adusei Energy security and the future of Ghana. Available *at: http://newsghana.com.gh/energy-security-and-the-future-of-ghana/* (2012) Accessed 3 July 2018.

[4]. F.Meghdad, M. Asher, G. C. Klumpner and Y. Liangzhong, "Novel Integration of DFIG-Based Wind Generators Within Micro-grids", *IEEE Transactions on Energy Conversion, vol. 26, no. 3, pp 840-850*, September 2011.

[5]. C**,** Seliliz, L.S. Wrightsman, and S. W. Cook. Research methods in social relations. *University of Michigan: Holt, Rinehart and Winston*, 1976.

[6]. A. Douglas, Halamay, and T.K.A. Brekken, "Factorial Analysis for Modeling Large-Scale Grid Integration of Renewable Energy Sources", *PowerTech, 2011 IEEE Trondheim*, pp 1-6 June 19-23, 2011.

[7]. S. Mukhtiar, K, Vinod, C. Ambrish, and V. K. Rajiv, "Grid Interconnection of Renewable Energy Sources at the Distribution Level With Power-Quality Improvement Features", *IEEE Transactions on Power Delivery*, vol. 26, no.l, pp 307-315, January 2011.

[8]. S.K. Khadem, M. Basu, M.F. Conlon, "Power quality In grid connected Renewable energy system: Role of custom power devices", *International Conference on Renewable Energy and Power Qualities, Granada (Spain), pp 1-6, 23-25*, March 2010.

[9]. G.C. Bakos, "Distributed power generation: *"A case study of small scale PV power plant in Greece"*, Applied Energy, vol. 86, pp 1757-1766, February 2009.

[10]. A. Etxeberria, 1. Vechiu, A Etxeberria, J.M. Vinassa, H. Camblong, "Hybrid Energy Storage Systems for Renewable Energy Sources Integration in Micro-grids: A Review", *International Power Electronics Conference (IPEC), pp 532-537*, March, 2013.

[11]. V. Foster J. Steinbucks, Paying the price for unreliable power supplies: in-house generation of electricity by firms in Africa. AICD. *Available at:* http://www.infrastructureafrica.org/system/files/library/2011/05/WP02_Own_generation.pdf 2008. Accessed 20 June 2018

[12]. D. Schulz, "Improved grid integration of wind energy systems", *Bulletin of the Polish Academy of Sciences Technical Sciences, vol. 57, no. 4, pp 311-315*, 2009.

[13]. A. Amiri M. Zibaei *(*Granger causality between energy use and economic growth in France using geostatistical methods. *Munich Personal RePEc Archive (MPRA) Paper 36357*. 2012

[14]. V. C. Ganti, Bhim Singh, S. K. Aggarwal, and T. C. KandpaI, "DFIG-based wind power conversion with grid power leveling for reduced gusts," *IEEE Transactions on Sustainable Energy, vol. 3, no. I, pp 12-20*, January 2012.

[15]. A Omran, Walid, M. Kazerani and M. M. A. Salama, "Investigation of Methods for Reduction of Power Fluctuations Generated From Large Grid-Connected Photovoltaic Systems", *IEEE Transactions on Energy Conversion, vol. 26, no. 1, pp 318- 327*, March 201 I.

[16]. Tidjani, F. Souleyman, C. Ambrish "Integration of renewable energy sources and the utility grid with the Net Zero Energy Building in Republic of Chad", *IECON 2012 - 38th Annual Conference on IEEE Industrial Electronics Society*, May, 2012.

[17]. D. Stroe, A. Stan, R.Diosi, R. Teodorescu, S. J. Andreasen. "Short term energy storage for grid support in wind power applications", 2012 *13th International Conference on Optimization of Electrical and Electronic Equipment (OPTIM)*, April, 2012.