Smart Grid: An Assessment of Opportunities and Challenges in its Deployment in the Ghana Power System

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Abstract – The concept of Smart Grid have in recent times being introduced around the world to make the grid smarter and more intelligent. Modernization of the grid will help with the integration of renewable energy resources, improve supply of reliable power, promote energy efficiency etc. The current status of the grid in Ghana is being studied. The potential, opportunities and challenges of Smart Grid deployment in Ghana are analyzed. The paper reviews Smart Grid technologies, the state of Ghana with regards to Smart grids, the opportunities and benefits. Furthermore, the paper discusses challenges and recommendations to address these challenges.

Index Terms **– Smart Grid, Renewable Energy Resources, Micro grids, Distributed Generation.**

1. INTRODUCTION

Ghana has a huge potential to grow its economy. This can be achieved through massive industrialization, job creation and ensuring wealth is evenly distributed.

The Ministry of Energy (MOE) in Ghana envisions to develop an "Energy Economy" that is capable of securing reliable supply of high quality energy services for all sectors of the nation's economy and subsequently becoming a net exporter of electric power by 2015 [12].

A national policy plan of the Ministry outlines plans to increase power generation capacity from the current 2000 MW to 5000 MW by 2015. Not only increasing power generation capacity but also more importantly expand access to electricity from the current 66% to universal access by 2020 [12].

A policy plan to promote clean energy technologies seeks to invest massively in renewables. The Ministry intends to increase the proportion of renewable energy in the total energy mix and ensure its efficient production, use and promote energy efficiency [12].

Expanding access to electricity, integration of decentralized power, often based on renewable energy resources, improving supply reliability and efficiency will call for an upgrade of the existing out-of-date electric power grid to a "Smarter Grid".

The purpose of this paper is to explore what opportunities are there for Ghana as the world moves from an out-of-date electric grid to a smart grid.

This paper first briefly describes the electricity sector of Ghana, reviews smart grid technologies, potential opportunities and benefits for the Electric Grid of Ghana and assess likely challenges that the sector is likely to face in the implementation of a Smart Grid.

The paper finally attempts to make some recommendations on things that have to be in place preceding the implementation of Smart Grid in Ghana.

2. Power Sector of Ghana

The power sector in Ghana comprises a competitive wholesale power generation; Volta River Authority which manages the Akosombo Hydro Plant, Kpong Hydro Plant and Aboadze Thermal Plant and Sunon Asogli Power Plant, an independent thermal power Plant; the Ghana Grid Company Limited (GRIDCo), the only transmission entity mandated to provide open access transmission for all generation facilities and Electricity Company of Ghana (ECG) and the Northern Electricity Department (NED), mandated to distribute power to customers in the southern half and northern half of the country respectively. The primary objective of the current structure spurned out of a power sector reform in 2007. This current structure is aimed at creating a competitive generation market which will be achieved by facilitating the entry of independent power producers (IPP) into the generation sector.

The Generation, Transmission and Distribution sectors mentioned above are regulated by three entities: The Ministry of Energy, Energy Commission and Public Utilities and Regulatory Commission.
The Ministry of Energy was established in 1978 responsible for the formulation, implementation, monitoring and evaluation of policies in the energy sector.
The Energy Commission was established in 1997 under the Energy Commission Act. The Commission was mandated to regulate and manage how energy resources in Ghana are

used. They also make recommendations regarding sectoral policies, issuance of licenses for public utilities and petroleum and gas activities.

The Public Utilities and Regulatory Commission (PURC) is mandated to regulate public utilities (electricity, water, etc.) in Ghana. This includes examination and approval of tariffs, monitoring quality of service and performance of utilities with respect to established standards of performance [16].

3. What Is A Smart Grid

A Smart Grid is defined as "a modernization of the electricity delivery system so it monitors, protects, and automatically optimizes the operation of its interconnected elements – from the central and distributed generator through the high voltage network and distributed system to industrial energy storage installations and to end-use consumers and their devices [6].

The IEA defines a Smart Grid as "an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users. Smart grids co-ordinate the needs and capabilities of all generators, grid operators, end-users and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimizing system reliability, resilience and stability"[9].

The Smart Grid may also be defined as an electrical power infrastructure that makes intelligent decisions about the state of the electrical power system to main a stable environment [16]. It uses sensors, communication, computational ability and control to improve overall functionality of the electric power delivery system.

With a Smart Grid, the grid is transitioned from a mostly unidirectional radial distribution system (one-way communication) to a multi-directional (two-way communication capabilities and information flow) to allow for active participation of end-users.

Fundamental technologies that will propel smart grid implementation as listed by the U.S Department of Energy and also mentioned in the IEA Report on Smart Grid Technology Road Map are:

- Integrated communications, connecting components to open architecture for real time information and control, allowing every part of the grid to both 'talk' and 'listen'.
- Sensing and measurement technologies to support faster and more accurate response, such as remote monitoring, time-of-use pricing, and demand side management.
- Advanced components to apply the latest research in superconductivity, storage, power electronics and diagnostics.
- Advanced control methods to monitor essential components, enabling rapid diagnosis, and precise solutions appropriate to any event.

4. Where Is Ghana With Respect to Smart Grid

A model which can guide the transformation of a power system forward toward a smarter grid is known as SmartGrid Maturity Model (SGMM) [1]. This model is being used by utilities to assess which stage they are at with respect to achieving a smart grid. The model helps in strategic business development decision making framework, investment and rate cases, building explicit plans on movement from a level to another, measurement of progress using key performance indicators (KPI's), bench mark and also learns from others [1]. The different levels used by SGMM to rate a utility are as follows;

- Level 0 – Just Started
- Level 1 – Initiating and Exploring: contemplating smart grid transformation; may have a vision but no strategy yet; exploring options; evaluating business cases and technologies; may have some smart grid elements already deployed.
- Level 2 – Functional investing: making decisions at least at a functional level; business cases in place and investments being made; one or more functional deployments under way with value being realized; strategy in place.
- Level 3 – Integrating Cross-functional: Smart Grid spreading; operational linkages established between two or more functional areas; management ensuring decisions span functional interests, resulting in cross-functional benefits.
- Level 4 – Optimizing Enterprise-Wide: Smart Grid functionality and benefits realized; management and operational systems rely on and take full advantage of observability and integrated control, both access and between enterprise functions.
- Level 5 – Innovating next wave of improvements: new business, operational, environmental, and societal opportunities present themselves, and the capabilities exist to take advantage of them.

A number of utilities have completed the SGMM assessment and results indicate most are just starting SGMM implementation [1]. It will be worth mentioning that Ghana is yet to start (Not yet at Level 0).

5. Benefits of Smart Grid To the Ghana Power System

This section presents benefits the electric grid in Ghana will derive from the implementation of Smart Grid technology.

- *Loss Reduction:*

There are two distribution companies in Ghana, the Electricity Company of Ghana (ECG) and the Northern Electricity Department (NED). The current loss level of ECG is about 40%. This consists of 10% technical, 20% commercial and 10% collection [13]. The financial implication of this current loss level is enormous compared to the 15% established benchmark [13].

Another study reveals that Transmission losses account for about 4-5% of total system losses with distribution losses (technical and non-technical losses) accounting for about 25% averagely [4].

High distribution losses are as a result of high non-technical losses. Non-technical losses are due to theft, inefficient metering etc. The transmission losses are as a result of insufficient reactive power compensation.

Smart grid can facilitate more effective reactive power compensation and voltage control. Distribution losses can be effectively addressed by through adaptive voltage control at substations and line drop compensation to levelize feeder voltages based on load [5].

The non-technical losses in the distribution system can be addressed through the deployment of smart metering infrastructure [14].

- *Peak Demand reduction*

The current situation in Ghana such that the peak demand is close to the amount of dependable generation available thus insufficient reserve margin. The system is expected to meet a target reserve margin of 28% [7]. With an annual projected demand growth of between 6-8%, the sector would have to massively invest in generation to meet this reserve requirement. This obviously would be very expensive.

The use of Smart appliances to manage customer demand will reduce the need for spinning reserve [2]. Smart appliances and equipment will also help reduce investments into expensive electricity supply to meet peak demand [GridWise 2010]. Doral et al, estimates a reduction of 1% in peak demand could result in cost reductions of 4%. This can be achieved by the implementation of demand response programs. The IEA estimates that smart grid deployments could reduce projected peak demand by 13% to 24% over the framework for the regions analyzed in their report.

- *Improve Reliability and Quality of Supply*

Smart grid implementation will improve grid reliability and quality of supply. Autonomous control actions by increasing resilience against component failures and natural disasters, eliminating or minimizing frequency and magnitude of power outages subject to regulatory policies, operating requirements, equipment limitations, and customer preferences by a smart grid will enhance grid reliability and subsequently quality of supply [11].

- *Enabling Distributed Generation and Microgrid*

The policy plan for the renewable energy sector is to have penetration of 10% by the year 2020. Renewable resources that may play a significant role may include and not limited to the following: wind, rooftop PV, fuel cells, solar farms, etc. Traditional power systems for safety reasons when integrating distributed generation set protection and voltage regulation of generators to avoid islanding during outage. Even though planned islanding is now being introduced, smarter grids offer the capabilities to efficiently provide power via microgrids in islanding situations [10]. With a universal access to electricity by the year 2020, this application will be desirable and cost-effective for rural areas.

- *Enabling Retail Markets*

Currently, there are no retail markets in Ghana. Although work is far advanced in the creation of a power market, nothing is mentioned about a retail market where end users will participate in the market. There are policies that are promoting integration of renewable resources into the energy mix but mostly at the utility level. Introduction of Smart Grids into the Ghana Power System will open up competition in the retail markets and provide entry for end-users/customers. Smart Grid also drives the integration of Green Power into the market [1]. This will require metering standards and communication protocols. Currently, there are voltage issues being experienced on the network due to insufficient reactive power. There is therefore an increasing need for the provision of reactive power compensation at the load or customer end. After recent tariff increments and adjustments, the customer and the Public Utilities and Regulatory Commission which regulates tariffs and power quality from Utilities have being focusing on power quality issues. With the introduction of quality bids in the retail markets, these issues can be catered for.

6. Challenges and Recommendations

This section of the paper outlines possible challenges that will come with the implementation of smart grid in Ghana. These challenges are immediately followed by recommendations to address them.

- *Smart Grid Framework, Legislation, Regulation and Standards*

There is currently no framework, legislation or standards for smart grids in Ghana. Prior to introducing smart grid in Ghana, common ground rules and business

practices for smart grid integration, cost recovery mechanism for utilities, demand side management policies need to be put in place. As a first step, a National Institute of Standards and Regulation (NISR) may be established to identify and evaluate existing standards, measurement methods and other smart grid related requirements. International smart grid frameworks, legislation, regulation and standards may be adopted and adjusted to suit the Ghana System.

- *Smart Grid and Renewable Energy Road Map*

Currently, there exists a road map and legislation for renewable energy. The same cannot be said for Smart Grid. Since smart grid technologies will be an increasingly important resource for integrating both utility-scale and distributed resource in the not too distant future, there is the need to ensure alignment of road maps between smart grid and scenarios for future renewable energy supply [10]. These should include scenarios for very intelligent transmission solutions and programs for distributed energy resources such as feed-in tariffs for small scale development.

- *Education and Capacity Building*

Achieving the vision of 10% renewable penetration and the significant role smart grids will play in renewable energy integration into the energy mix will require some level of expertise in renewable energy and smart grid technology. Policy makers have some appreciable knowledge in renewable energy resources. This was achieved through education and seminars. The same cannot be said of smart grids technology and its role in renewable energy integration. Additional work force for smart grid implementation (implementation, operation and maintenance) will require engineers who have working knowledge in not just power systems but knowledge in communications. These engineers should be competent enough to handle issues with the design and operation of communication technologies that overlay the power distribution system [10]. Most of the experienced engineers in the power industry are at managerial positions leaving the young engineers do most of the fields work. These young engineers will be at the forefront of Smart grid implementation, operation and maintenance.

It will therefore be significant that the following be done in preparation for a Smart grid project in Ghana:

- Universities and Industry players in the power sector should invite experts and experienced business professionals to provide introductory courses and workshops in Smart Grid technology, and the role of smart grid in the power industry.

- The Engineering Universities in Ghana should be encouraged and provided with necessary funding to develop and deliver curricular in smart grid technologies. This will help train engineers and scientist to develop and implement smart grid technologies.

- The Ministry of Education in collaboration with the Ministry of Environment, Science and Technology and Ministry of Trade and Industry should promote entrepreneurs to create new smart grid businesses and business units.
- Polytechnics, Vocational and technical training institutes should be encouraged to train technicians in the necessary skills that utilities may require to installing and maintaining smart grids.

- Programs should be put in place to provide technical training in smart grids and also to provide policy makers with necessary education that will make them understand the possibilities and promise of a smart grid in the 21st century grid infrastructure.

7. CONCLUSION

An overview of the current power sector in Ghana has been discussed. Smart grid technologies have been discussed and the Smart Grid Maturity Model has been used to determine the status of Ghana with regards to Smart Grid. With a policy direction of 10% renewable integration by 2020, the opportunities Smart Grid presents to the power sector with regards to renewable integration and advantages to the whole power sector has been discussed. Finally, likely challenges to be faced with Smart Grid implementation with corresponding recommendations have also been looked at carefully. It is the hope of the author that, a task force will be set up to start all processes to draw a comprehensive road map to smart grid implementation.

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