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Roadmap toward Smart Grids in Hydro and Thermal Power System: A Case study of the Ghanaian Power System

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ABSTRACT: The evolution of Smart Grid flings fresh applications and opportunities to enhance the efficiency of power distribution networks. Network operators have the opportunity to make use of different sources of power. Communication between the network operators and the consumersis constantly permitted to allow optimization and balancing of energy usage. This paper seeks to evaluate the state of the Ghanaian Electric Distribution Network with respect to Smart Grid. We evaluate the performance of the traditional distribution network since its partial incorporation with the Smart Grid elements. The operations of the Supervisory Control and Data Acquisition, the Automated Meter Infrastructure and Circuit Breakers are specifically addressed. Road map to optimizing the distribution network in Ghana is presented.

It is concluded that optimizing these key elements will transform the role of the distribution system and ensure a safe and reliable power network.

KEYWORDS: Smart Grid (SG), Supervisory Control and Data Acquisition (SCADA), Automated Meter Infrastructure (AMI), Circuit Breaker (CB), distribution network and optimizing.

I.INTRODUCTION

The conventional electrical power network consists of systems of power generation stations, transformers, facilities of storage, transmission lines, and distribution networks that render power supply to domestic, commercial and industrial users [1]. It is based on centralized power generation with one-way distribution and well known fixated topology. Hence, the control and protection can be well optimized for such systems.

Presently, the electricity generation in Ghana has mainly been from hydro and thermal sources. Renewable energy on the other hand has been considered to add up to the electricity source to expand power source. Usually renewable energy source such as sun and wind have a stochastic behavior. Therefore, the involvement of distribution renewable energy, for example, by customers will add further challenges to the power network. The sum of the power generated for all the existing plants as at the end of 2018 is 14,069 Gigawatt-hours (GWh), with hydro making up 39.9%, thermal contributing 59.9% and solar producing below 0.5% [2].

The generated power is transmitted over a distant network of power transmission, to distribution networks before finally supplying the consumer, in a typical unidirectional power feed mode, from the generation point to the consumer premises [3], [4].

The Volta River Authority (VRA) generates electricity whilst the Ghana Grid Company (GridCo) takes charge of the transmission system. The grid mainly transmitted at 161kV covers approximately 5,100 km. The grid could be transmitted at 69kV, 225kV, and 330kV. The generated power is carried from the generation stations to nearly fifty-five (55) substations. The voltage is let down at the substation to lesser voltages including 34.5 kV and 11kV. The voltage level is reduced to suit the distribution companies; Electricity Company of Ghana (ECG), Northern Electricity Distribution Company (NEDCo) and Enclave Power Company (EPC).

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The ECG is the principal power supply firm supplying 3.1 million domestic and business customers in the Ashanti, Central, Eastern, Greater Accra, Oti, Western, and Volta regions.

NEDCo in 1987 was established to distribute electricity to Upper West, Upper East, Northern, and Brong-Ahafo regions of Ghana. The NEDCo currently extends to two-thirds of the landmass of Ghana in terms of operation.

A privately owned distribution company Enclave Power Company (EPC) in Tema is the main power supplier to the Free Zone (FZ) industries.

The received power from the GridCo is stepped down to 11kV to the industrialized community and 440/230V to the non-residential and residential consumers.

With GDP growth of 7.4% as at the last quarter of 2019, the demand for electricity is growing daily, the users' are increasingly requiring for quality and reliability from the service providers, new challenges and opportunities for the industry [4]. Owing to the service providers' zeal to meeting the electricity needs of the growing population. It has introduced some feature of the SG with the aim of integrating it into the existing traditional grid. That will make room for real-time monitoring. It will actively enable the flow of both electrical energy and information. This will fit present and new forms of power supply and also will ensure power delivery is secure, efficient and reliable [5], [6]. This infrastructural migration undoubtedly will help the industry to better the performance, increase reliability and utilization. Integration of renewable energy, automation, quick demand response, quality energy and low maintenance cost are extra benefits of the infrastructural movement [7]. Furthermore, renewable energy do not necessary be controlled by the central control of the traditional power plant. Hence, new distribution and smart control system is needed for such distributed generation. Distributed control and protection system require reliable communication as well as efficient data analysis. Hence, advance ICT technologies will have major role in smart grid.

Figure 1: A primary substation

Yet, this system migration does not come without challenges. This paper therefore seeks to present some of the challenges associated with the upgrading of the old-fashioned grid focusing particularly on the SCADA on the transmission network, CB installed at the secondary substation and AMI at the customers' premises. It also presents feasible solution to ensure the optimum performance of the Ghanaian distribution network.

II.SYSTEM MODEL AND ASSUMPTIONS

Generally, the out-dated grid is going through some major alterations and investments to secure reliable grid performance, more efficient and viable energy use. This will only be realized with the introduction of SG elements. The Department of Energy (DOE) based on its vision of grid 2030 were first to bring to light the concept of SG as a prophecy for the electric delivery systems for the future. The SG, partially defined as a power network that employs ICT in integrating all consumers joined to the power network bearing in mind their doings and actions in a smart way.

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The SG will make room for renewable energy integration; load monitoring, energy storage, system transparency and cyber security [6], [9], [10]. The SG enhances automation, connectivity and coordination between different suppliers and consumers [11].

Thus, SG is an umbrella term and key enablers that covers transformation of both the transmission and distribution grids and will become a substantial part in the configuration of future electrical power systems. The notion of a SG is that of a digital upgrade of transmission and distribution grids to jointly elevate present systems by reducing the losses, and also open up fresh markets for different energy production. Many countries in the world are involved in this big trend [1], [11].

The Ghanaian distribution power network is gradually strengthened by the introduction of the technological innovation such as the SCADA, AMI, and the CB into the existing legacy electric grid [3].

IEEE has defined the standards and road map for the SG, thus the P2030 formation. Agreeing to the United States Department of Energy's Modern Grid Initiative report, essential features of SG includes: been curative on its own, been able to accommodate consumers' participation in the grids operation, been balky to attack, and been able to produce quality, efficient and reliable power at lower rate. Encapsulate diverse power sources and options for storage; enable electricity markets to flourish, run more efficiently [12], [13].

Comparison between the traditional grid and the SG is presented in table 1.

Traditional grid	Smart grid
Few market customer choice	Many market customer choices
No means of energy incorporation	Means of energy incorporation
Non self-monitoring and non-self-healing	Self-monitoring and self-healing
Difficult to redirect power	Easy to redirect power

Table 1: Comparison between formal grid and SG

We elaborate on the opportunities and challenges associated with the integration of these smart features with the conventional energy grid.

The SG capacity of transmission could rise meaningfully to a safe level guarded from the current heckle affecting the aged network, this would bridge over the energy supply and demand, expand the quality of power and reliability of power supply and thus link up bulky aggregate of distributed generation systems of several systems. The concept of using a system of multi-energy sources to achieve a coeval result, integrated into the LV distribution network to serve near residence is termed distributed generation (DG) [14].

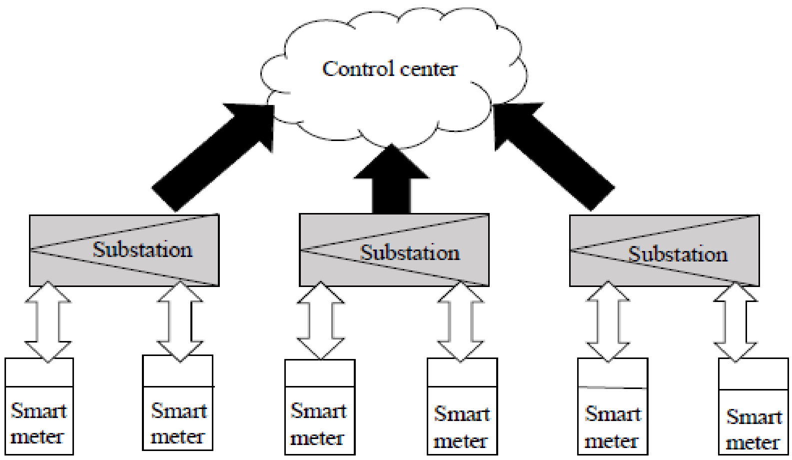

Figure 2: Smart grid distribution network.

Computation and communication feature are combined as well as advanced sensor and controlling technologies in the smart distribution grid technology [14]. With automatic control power interruptions are reduced. Rate of failure is brought down; outage time reduced drastically and thus an improved and efficient transmission of power line ensured. Operation and management cost reduced as well and profitability assured automatically.
However, some parameters must be taken into accounts when applying the SG, these includes; minimization of technical losses by planting the power source bordering to the feeding region; integration of renewable energy sources to supply at lowest rate in the market [1].

A. SCADA
SCADA in electrical sense refers to a system of technologies that empower remote monitoring, coordinating, and operating distribution mechanisms in a definite time mode from distant positions [7]. In industrial organizations, the SCADA systems are used for controlling and maintaining efficiency, for distributing data for smarter decisions, and for system communication issues to help extenuate system downtime.
SCADA implementation in power scheme expands the general effectiveness of the scheme in terms of optimization, supervision and control of the generation and transmission systems. Operating it in the energy system offers numerous network dependability and constancy for integrated grid set-up [15], [16].
Yet, with such benefits there are equally challenging and pressing matters linked with it that must be looked at thoroughly. Considering the terrain and the contour of the earth in which the SCADA is been operated here in Ghana and by the ECG. It is worth saying that, to ensure the full benefits of this initial integration, it would be of greater benefit to have an accurately designed communication network. To facilitate the connection between Remote Terminal Units (RTU) and the SCADA master control. Amongst the communication networks are microwave, optical fibre line, cellular, satellite, Wi-Fi etc. Multiplicity of communication options must be considered to meet needs. It is therefore necessary to always ensure the SCADA is up-to-date;Artificial Intelligent (AI) algorithms must be employed to extend the capability of the control system [19], [23].
Moreover, ample control systems in the system have little designed security measures for home-grown control and the system is not hardy to errors from unintentional miscommunications or operational error. It is therefore necessary to provide security in terms of limiting entry to systems and network equipment from unauthorized bases. Ensuring the system is hardy to gain illegitimate access to the network.

B. Automated Meter Infrastructure
The AMI is arguably the most implemented element of SG worldwide as it is seen as the first step for power services providers to locomote towards the SG. A metering device is classified as smart when it can keep records of the power and other vital parameters on a frequent basis and which is capable to interconnect this information to the central system for monitoring and analytical purposes [1], [12], [17]. These data can be used to monitor the network conditions such as the distribution state estimation, advanced distribution operations, advanced transmission operations, and advanced asset management [18], [20].

The AMI communicate to the central system through communication means such as Local Area Network (LAN), Wide Area Network (WAN), Bluetooth, Zigbee, Global System for Mobile (GSM), General Packet Radio Services (GPRS), Fourth Generation (4G) and Fifth Generation (5G). Thus, the AMI implementation establishes the common telecommunications and IT infrastructure. These form the foundation for the future of smart grid [19].

The AMI offers numerous prospects to increase quality of energy and reliability by means of examining the customers supply state, including voltage level, current state, imbalances in phase and harmonic values. Therefore, the AMI on a constant base gathers all statistical information related to customer supply [1].

Before the introduction of the AMI, the main energy distributor in the southern part of Ghana had relied solely on the conventional meter readers and meter investigators for meter readings monitoring and information from meters. Many issues then were charges from customer of over-billing, wrong billing as result of wrong reading and estimated bills due to non-access to meter, accusation of tempering with meters and counter defence of having not.

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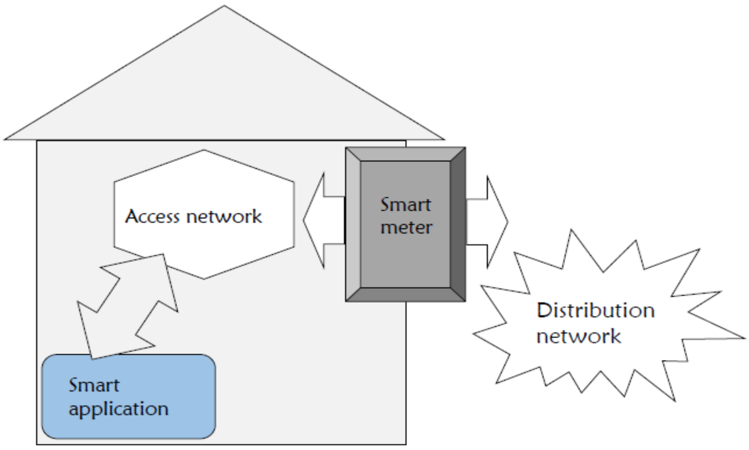

Figure 3: A smart meter collecting data

However, smart meter allows for two-way communications where it sends data and receives data [12], thus a smart meter offers the SG interface between consumer and the energy provider. The smart meters fixed in the existing location of the analogue meters or fixed at new places in new premises, these meters are digitally operated, allowing automation and complex transfers of information among customer's premise and the utility provider [3].

It is also skilful in determining instantaneous voltage and current of the consumer, processors are built in the smart meter and can therefore estimate instantaneous power, total energy usages and power factors [20], [21].

With respect to the power service provider in the southern Ghana, important activities has taken place with respect to the AMI, aiming at placing smart meters in homes and offices to quantity and monitor electricity. Yet, the types of AMI installed so far are affected mostly by problems such as *faulty relay* which causes the supply to be cut off at any time. *Blank screen* which in some instants allow flow of energy to the customer and in other instance cut off supply. The screen of the meter could go blank as a result of loose contact at the User Interface Unit (UIU) or at the meter terminal. *Blank Screen* also occurs due to huge drop in voltage level.

C. Circuit Breaker

Amongst the functions of the circuit breaker is the capacity to break up faulty current to an indicated value and reforming the phase link when the faulty current is eliminated. By several input signals that define the state of the circuits secured by the breaker, this operation is repeated many times between maintenance periods.

The company had made use of the oil immersed CB at the secondary substation for preventive measures and still making use of it. Recently, as bent as the company is to maintain a very stable and swift response to power interruption, the CB at the secondary substations were introduced to replace the conventional fuse on the LV networks. The CB is a good option for fuses. A fuse operates once and then has to be replaced once it's blown.

When a CB detects a faulty current, it instantly by using the mechanical energy stored opens its contacts to interrupt power flow to the circuit. Implementing the CB at the secondary substations posed some key challenges. A conventional individual fuse will blow when a faulty current occur on a particular phase.The CB is not able to differentiate on which phase the fault current occurred. Thus, in the case of the CB the whole three phases go down since the operation mechanism is combined. This automatically increases the outage configuration. In order to restore supply the cause and type of faults should be known to overcome the fault in the circuit. Though, it is meant to perform automatic closing function, due to the terrain and type of faults which usually are short circuit turns to destruct the operation. Making it a self-destructive, requiring manual reset. With the assistance of manual control knob to switch off the load or reset a tripped breaker, the CB is then reset manually to restore supply.

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III.SUGGESTION ON THE TECHNICAL ROUTE OF SG IN GHANA

Having presented the state of the national grid it's worth laying down the necessary road map to optimizing the grid[22]. Looking at the SCADA it is very paramount the company do away with the issues of SCADA operational breakdown most often during rainy season.

Undoubtedly, the communication is mostly perfect during sunny days and dry season.On a stormy day whenoperation to try restoring supply to a tripped feeder as early as possible is not getting through, the operator has not any means than to wait for the natural phenomenon to cease before restoring supply. Due to event such as this, changes must take place; robust means of communicating, monitoring, controlling and protecting of transmission network must be employed. A strong communication infrastructure is needed for the SG.

For energy service betterment in relations to automation and optimisation and for the support of the tactical activities in the dynamic power systems the Energy Management System(EMS) should be applied on the base of the SCADA functionality [23].

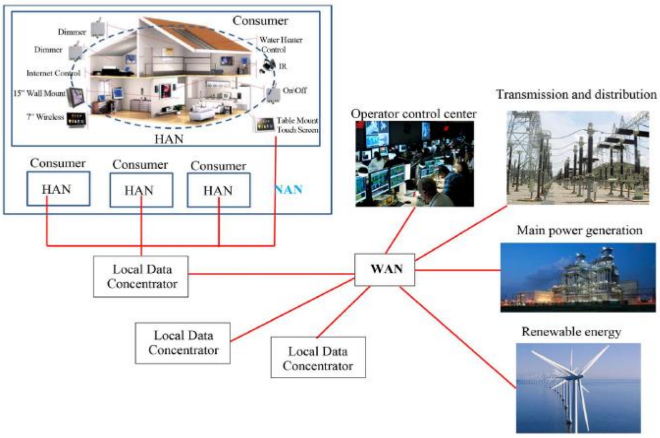

Figure 4: SC Communication Infrastructure [24]

The installed smart meters are mostly affected by date and time drift (update), where there is not synchronisation between the meter time and the system time. *Blank Screen*, happens due to mechanical failure or lightning bolts hitting meters without proper earthing system. Though, some blank screen meters still flow power some do not. When cable connections from the UIU and at the main bus on the meter terminal are not properly connected, it causes theUIU to go blank.

Faulty Relay is the core of all the problems affecting the smart meters so far, some relays are reset by entering a system generatedtwenty digit codes (00000000000115061984). Relay must be reset and meter terminal cover must be fixed well to fix an opened relay.

A technical route that establishing multi energy source and ensures an improve power supply network is needed, to promote economic development and distributed energy technology such as wind energy and solar energy. In so doing distributed energy should be given rapid attention to ensure anall-inclusive energy sources to curtail the power deficiency in Ghana. Intelligent scheduling systems shouldbe builtfor the LV network to help mitigate fault on the distribution networks. Micro-gridtechnologies should be established to help mitigate the deficit of energy shortage in rural areas [22].

IV.SECURITY

As acknowledged by all major industry players the necessities for converting their conventional static grids into modern and dynamic SGs. To ensure robust, reliable, viable and naturally friendly electrical energy system to users, a completely SG operational system needs to be established in the Ghana distribution network. That would facilitate extra receptive load control, offer reduce technical losses and escalate the relation of using renewable energy in the power system.

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The government must encourage and boost the use of renewable energy. Specifically solar energy and wind energy. That will ease the pressure on the national grid. It will also serve as means of cutting carbon emissions. Renewable energy is not ordinarily used in Ghana. Introducing it would possibly emanate customer from mere consumer to "prosumer" where they will be able to also produce power from the renewable energy and supply to the distribution network.

Though, the wind power plants are less expensive there is a wide spread of lack of wind flow permanency as a hurdle but this could be dealt with by the implementation Artificial Intelligence (AI) algorithm.

The government of Ghana should demonstrate responsiveness towards technical facets in the road ofbuilding a complete smart grid system. Intensify capacity building and load regulations and lay downfresh green energy processing system.

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