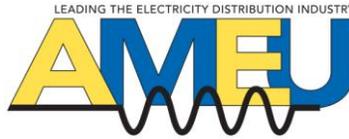


Smart Grid Evolution through Microgrid Aggregation in Africa



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1. Introduction:

Smart grid vision integrates a whole host of software and hardware solutions with the aim of modernizing the power grid across its entire value chain. This comprises solutions that aim to optimize the process of energy delivery and utilization, starting at the high voltage transmission grid, going through the medium voltage distribution grid, and all the way to low voltage consumption. This vision requires close collaboration and commitment from a variety of stakeholders, comprising policy makers, utilities, industry, academics, and consumers. Smart grid means different things to different people; therefore, it has to be customized to address the particular drivers and pain points of the utility, and be executed in a phased approach. Furthermore, it is extremely important to have solutions that are interoperable and standards-based in order to prevent monopolies and technology obsolescence.

Central to the smart grid vision is the aim to increase energy efficiency and enhance power system reliability. Energy efficiency relates to power grid losses, whereas reliability is closely tied to outages. The traditional power grid topology is based on one way power flow from a centralized power plant through a massive grid of various voltage levels to the end users. One way to reduce technical losses incurred through the energy delivery process is to reduce the power transmission distance by utilizing distributed energy resources (DER) placed close to the loads. The use of DERs, e.g. diesel, wind, biomass, rooftop solar, etc. can increase power availability and enhance reliability. The integration of DERs obviously changes the traditional topology of the power grid and opens

the door for two-way power flow, whereby the consumers can become producers and feed power to the grid, hence the notion of “prosumers”. However, some DERs may pose a big challenge for integration into the power grid; for example, solar and wind power generation are naturally intermittent, causing the DER generation output to be unpredictable and fluctuant; hence putting the system’s safety at higher risk [1]. Therefore, incorporation of big chunks of such resources requires advanced solutions to facilitate such integration. This change in power grid topology could not have been possible without the sophisticated smart grid solutions such as microgrid.

2. What is a Microgrid?

A microgrid (MG) is a miniature representation of the bigger, or macrogrid. It comprises local power generation, local load, and an advanced control system. It may be connected to the larger grid through a connection bus, or may be completely isolated and operate in an “island” mode. Furthermore, it may include community energy storage (CES) to store excess energy from renewable resources such as wind and solar, which will compensate for power loss caused by intermittency. Such approach will not only solve the interconnection of large DER with large power system but it can also benefit the customer as users can be supplied power even during outages[1, 2 ,3]. Moreover, storage devices provide the amount of power required to balance the system following disturbances and/or significant load changes. Figure 1 shows

a typical configuration of a grid-connected microgrid system.

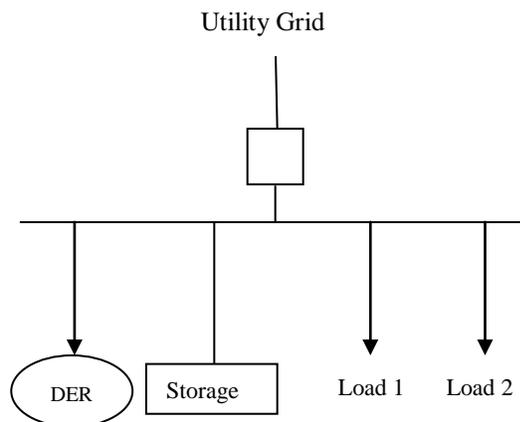


Fig. 1: Grid-connected microgrid configuration

Whether the MG is grid-connected or islanded, an advanced control system is needed to take the appropriate actions for load and generation management. For example, in the case where the MG is connected to the larger grid and the tie connection is lost, the control system will take appropriate actions that might include load/generation shedding to maintain the load-generation balance in the islanded area.

The control and management required for MG operation is different than traditional power system control, as MG is modular and may contain different generation type equipment with different characteristics and dynamics, containing short/long term energy storage components to stabilize the system. Hence, there are two main types of MG control: advanced unit-level control and system level integration control [1]. The unit grade controller which includes DER and load controllers, execute system level controller commands in addition to local information allowing decisions to be made with respect to voltage or frequency control. The MG system level control also called MG central controller where orders are given according to market information for dispatching purposes as well as making system's decisions based on information interactions among controllers.

The main objectives of using microgrids are to facilitate integration of distributed renewable energy resources and to provide high quality and reliable energy supply to critical loads.

Microgrids benefit the overall power utility by deferring major investments in power generation plants and transmission and distribution infrastructure. They also enhance reliability as a result of their ability to respond quickly to maintain the generation-load balance during disturbances. Microgrids have four operating stages, in all of which reliability must be ensured: 1) transient stage of going to grid-connected mode. 2) Steady stage of grid connected mode. 3) Transient stage of going to island mode. 4) Steady stage of island mode [1]. The stage of island-mode operation is affected by power quality, capacity of energy storage device, communication networks and types of DER. The management strategy in this mode of operation depends mainly on the local climatic conditions, load demands, fuel consumptions and power quality.

3. Microgrids & Rural Electrification for Sub-Saharan Africa (SSA):

Electricity is undoubtedly crucial to human development, and plays a vital role in facilitating essential activities for end users. The rate of electrification of a certain community can be used an accurate measure of its level of energy poverty [4]. Many countries do not have the capacity to build large centralized generation plants or transmission infrastructure. There are now an estimated 1.5 billion people without electricity in developing countries, and 85 percent of them live in rural areas [5]. In 2009, Sub-Saharan Africa (SSA) had about 585 million people without access to electricity, with urban electrification rate standing at 59.9% and a rural electrification rate of 14.2% where most of the available supply is unreliable [5]. Fig. 2 shows a global picture of the numbers (in millions) and the percentages of people without electricity.

The study conducted by the world Energy Council (WEC) in 2004 highlights the fact that Africa could be energy self-sufficient due to the various ample resources. However, this is not possible as these resources are at wide disparities in access to electricity [6].

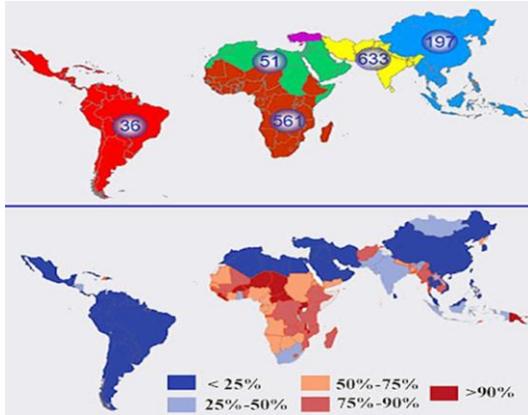


Fig 2: Number (Millions) and % of People without Electricity, 2008, Source: WHO & UNDP

In many cases, grid extension is often highly costly and not feasible in isolated rural areas, or is unlikely to be accomplished within the medium term in many areas. This is particularly true for SSA, where the vast land area and terrain nature pose big challenges for grid extension. In such situations, microgrid systems can be installed locally in rural areas to provide capacity for both domestic appliances and local businesses. Microgrids have the potential to become the most powerful technological approach for accelerated rural electrification. It is quite possible to incorporate isolated MG to meet demand of rural communities without wearing heavy financial resource [7]. Microgrids can be used as basic building blocks for future system expansion.

The combination of renewable energy sources with a genset has proven to be the least-cost solution for rural communities, as the benefits and advantages of each technology complement each other [8]. In the case of SSA where transportation of diesel for power generation in rural areas can be very costly, renewable resources can be used as the primary source of power generation. This primarily comprises solar and hydro, while diesel can be used for back-up generation. Hence, an additional benefit is realized through mitigation of carbon emissions, thus contributing to sustainable development and helping in the battle of fighting climate change. Furthermore, MG concept can influence the market and level of competition for prime sources of energy. It helps reduce dependency on imported prime fuel sources and support in regulating prime fuel market competition.

The proliferation of these individually controlled small microgrids paves the way for eventually aggregating them into an integrated and interconnected smart grid with improved efficiency, enhanced reliability, and environment protection through renewable integration. Multiple distributed microgrid controllers could eventually be integrated with a master distribution management system (DMS), using an appropriate communications infrastructure, most likely IP-based, thus forming an important element of the end-to-end smart grid vision for the utility.

4. Micorgrid Deployment Challenges:

Although MG presence sounds practical and provides feasible solution to increasing energy demand, utilities are cautious in integrating dispersed generating units to their systems [7, 9]. Clear and consistent policies are required to support this initiative. Other challenges can be categorized into non-technical and technical.

- Non-technical Challenges:

Deployment of microgrids involves complex financial and organizational questions [8]. The bottlenecks for the sustainable success of microgrids are not the technologies, but financing, management, business models, maintenance, sustainable operations, and socioeconomic conditions. Each community presents a cluster of characteristics and interests which will define the best technical solution according to local financial, social, and environmental terms. In addition, pricing, incentives, risk responsibility and interconnection standards and regulatory control must also be addressed

- Technical Challenges:

Urgent concerns and needs must be tackled such as safety, islanding, restoration from scheduled and unscheduled outages, power quality liability, capacity and reserve management [7, 9]. Additionally, other challenges including interconnection requirements, level of penetration and power exchange are imposed by utilities [1, 10-13].

5. Conclusion:

Despite the various challenges facing microgrids, the merits of such systems are definitely worth their penetration, especially in rural/remote areas. It will ultimately change how electricity is generated and its impact on human development. It will also enhance the efficiency of the use of local resources, help meet the demand regardless of geographic location, and reduce the impact on the environment. However, some measures need to be addressed by all stakeholders involved in the energy sector to facilitate a safe and reliable MG integration. MG systems form a viable solution for rural and remote electrification in general and for SSA in particular, and can form the basic building blocks for a future smart grid evolution.

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Biography:



Dr. Ahmad has over twenty years of design, management, teaching, research, and training in the various areas of electrical engineering, comprising power, control, electronics, instrumentation and automation. He has held leading positions at premier international companies, and taught at several colleges and universities. He has also been heavily involved in the development of local and international training programs for university students. He also taught several courses for engineers working in the utility and oil industries in the region. Dr. Ahmad joined GE in 2007 as Principal Engineer in Energy Consulting to provide power system consulting services to regional customers. He has assisted in several utility projects involving addition of new power generation. Dr. Ahmad is currently "Technical Marketing & Solutions Director" at GE Digital Energy. In his role, Dr. Ahmad provides expert support to GE and customers on smart grid/smart city solutions and road maps.



Dr. Lana El Chaar, Senior Marketing Development Manager, joined GE Energy Regional Marketing team in Dubai in June 2011. In her role, Dr. Lana conducts market studies to design business strategies for growth within the energy market for GE Energy's products. She overlooks the regional energy efficiency market dynamics and policies, while assessing the impact of market regulations and barriers on this sector. Dr. Lana is leading market development activities and design of business strategies supporting profitable growth for various businesses including Gasification, Industrial Solutions, and GE Oil & Gas. Prior to joining GE,

Lana was Assistant Professor at ADNOC's Petroleum Institute in Abu Dhabi, where her research activities focused on renewable energy applications in the Middle East.