Energy Storage Opportunities and Pitfalls in Sub-Saharan Africa: The Value of Standards

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OUTLINE

- Overview of Africa and West Africa electric power sector
- Regional grid interconnections and power pooling
- Distributed generation as viable solution for remote power systems
- Integration of renewables as key driver for energy storage
- The need for standards
- Conclusion
17 of the top 20 countries with high electricity deficit are in Africa.


Note: These countries account for more than 81 percent of the global access deficit.

Top 20 countries for access deficit in electricity, 2014.
Africa has the highest population without access to electricity

Africa has the fastest growing population
Sub-Saharan Africa is not keeping up with population growth for electricity access.
Energy is linked to all the remaining Sustainable Development Goals

Sustainable Development Goal on Energy (SDG7): ensure access to affordable, reliable, sustainable and modern energy for all
Africa is fairly endowed with significant energy resources for electricity generation, but they are underdeveloped and unevenly distributed.

Energy storage is a crucial tool for enabling the effective integration of renewable energy and unlocking the benefits of local generation and a clean, resilient energy supply.

There is a limited energy storage market activity in Sub-Saharan Africa to date.
OVERVIEW OF AFRICA ELECTRIC POWER SECTOR

Electricity Generation by Fuel – Africa (GWh)

2015

- Fossil thermal: 80.35%
- Nuclear: 1.56%
- Geothermal: 0.57%
- Solar & Wind: 1.38%
- Biofuels and waste: 15.87%
- Hydro: 0.27%

782,977 GWh
OVERVIEW OF AFRICA ELECTRIC POWER SECTOR

Electricity Generation by region – Africa (GWh)

2015

- South Africa: 39%
- East Africa: 6%
- Central Africa: 4%
- West Africa: 8%
- North Africa: 43%

Total: 782,977 GWh
Africa’s existing power transmission system (defined as lines with a voltage equal or above 100 kV), has a total length of 89,731 km.

It is small compared to the area of the continent, corresponding to a density of 3.29 m of transmission line per km².

Absence of a unified or standardized specifications: **Africa has at least 15 levels of transmission line voltages from 100 kV to 700 kV** (AfDB, 2014)
AFRICAN REGIONAL POWER POOLS

- Challenges of interconnected grid systems
  - Load and frequency control
  - Technical compatibility and operational coordination
  - Difficulties of joint planning and operation
  - Capacity building and compliance
  - Regulation enforcement

- Why Power Pool?
  - “Power pools are the best strategy to deal with Africa’s energy problems” - UN Economic Commission for Africa, 2005
Benefits of Interconnected Grid Systems

- Exchange of peak loads & Increase diversity factor
- Economic efficiency
  - Better utilization of the most efficient generators
  - Capture economies of scale for new projects
- Security and reliability of supply
  - Increase diversity of primary energy sources
  - Larger systems are more robust against contingencies
- Reduced plant reserve capacity
- Resource sharing
- Reduced investment in generating capacity
The West African Power Pool is divided into Zone A and Zone B.
THE WEST AFRICAN POWER POOL
The Challenge

- Regions must have:
  - Fairly developed grid infrastructure
  - Adequate generating capacity
  - Legal framework for cross-border trading
  - Regional institutions and regulations
- Change in mindset from a national to a regional/global mentality
- Transmission Regulation:
  - Transmission investment
  - Access to network
  - Network pricing
DISTRIBUTED RENEWABLE GENERATION

- Urban–rural divide in terms of access to modern energy and other services
- DRG allows for reduced electrical losses from transmission and distribution by locating generation close to the point of use
- DRG is modular and can be tailored to end-user requirements
- DRG is more able to match growing demand by using smaller units, thereby reducing the impact of large stepwise additions to centralized generation capacity.
| With high penetration of DRG the mini/micro grids becomes dynamic, distributed, networked, and fairly easy to integrate into a central electric system |
| The importance of intelligent and enabled technologies such as sensors, IEDs, and network management systems must not be overlooked when planning small or large scale distributed generation |
| Good planning, appropriate requirements and clear regulations for mini/micro grids limit the risk of stranded assets and enable better business cases for the involved stakeholders |
- Technical insights include preparing the micro/mini grid for integration into the centralized grid in the planning stage.
  - When the centralized grid expands into the area of the micro/mini grid, it can then directly connect to the micro/mini grid, with the micro/mini grid operating as a cell to the centralized grid.
  - To achieve this objective, the micro/mini grid equipment needs to comply with the technical requirements of the centralized grid.
Energy storage devices perform a wide variety of different functions at distributed and central levels:

- Permanently integrating renewable energies
- Backup for higher network stability
- Covering load and production peaks
- Implementing stand-alone networks for greater autonomy
- Protection in the event of blackouts
- Relieving the load on supply systems
- Optimizing consumption profiles
Classification of energy storage systems

- **Electrical energy storage**
  - Electrostatic energy storage: capacitors, super-capacitors
  - Magnetic/current energy storage: Superconductor Magnetic Energy Storage (SMES)

- **Mechanical energy storage**
  - Kinetic energy storage: flywheels
  - Potential energy: pumped storage, compressed air

- **Chemical energy storage**
  - Electrochemical energy storage
  - Chemical energy storage
  - Thermochemical energy storage

- **Thermal energy storage**
  - Low temperature energy storage
  - High temperature energy storage
Energy storage applications into the grid

Transfer of the available energy during off-peak periods to the high demand periods

Peak demand for power supplied by peaking plant, running only a few hours each day

Storage discharging into network

Storage charged from baseload generating plant

Storage used to maintain frequency and voltage by balancing supply and demand

Load
Storage
Power plant

A Renewable energy
B Commodity arbitrage
C Transmission support
D Distribution deferral
E Power quality
F DG support
G Off-grid
Continuous supply of quality power through renewables can only be ensured through the incorporation of battery storage systems in the setup.

Energy storage is one of many tools for aligning non-dispatchable renewable energy generation with load demands.

Wind and solar energy are available when weather dictates - not on command => Generation does not necessarily correspond to demand.

The reverse challenge arises from energy generated when load demand decreases.
Technologies for storage can be viewed as either primarily power technologies or primarily energy technologies.

- **Power-to-Energy ratio >= 2:1**
  - Power Technologies

- **Power-to-Energy ratio <= 1:2**
  - Energy Technologies

Source: Manz et al., 2012
### RENEWABLE ENERGY AND ENERGY STORAGE

#### Applications of energy storage

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
<th>Value</th>
<th>Type</th>
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</thead>
<tbody>
<tr>
<td>Financial Energy Arbitrage</td>
<td>Buy low, sell high</td>
<td>Displaces most expensive generation</td>
<td>Energy</td>
</tr>
<tr>
<td>Generation Capacity</td>
<td>Contribute to adequacy/reserve margin requirement</td>
<td>Defers investment in new generation</td>
<td>Energy</td>
</tr>
<tr>
<td>Equipment Capacity</td>
<td>Reduce flow through overloaded lines and transformers</td>
<td>Defers investment in new equipment</td>
<td>Energy</td>
</tr>
<tr>
<td>Line Congestion</td>
<td>Time shift delivery of renewable energy during congestion</td>
<td>Delays transmission line reinforcement</td>
<td>Energy</td>
</tr>
<tr>
<td>Wind and Solar Power Smoothing</td>
<td>Reduce ramp rates of wind and solar plants</td>
<td>Contributes to reserve and regulation requirements</td>
<td>Power</td>
</tr>
<tr>
<td>Frequency Regulation</td>
<td>Rapidly inject and remove power for short intervals</td>
<td>Contributes to regulation requirements</td>
<td>Power</td>
</tr>
<tr>
<td>Spin and Non-Spin Reserve</td>
<td>Dispatch power in &lt;10 min</td>
<td>Contributes to system reserves</td>
<td>Power</td>
</tr>
<tr>
<td>Governor/Inertial Response</td>
<td>Provide dynamic functional equivalents of synchronous generators</td>
<td>Reduces severity of frequency excursions events</td>
<td>Power</td>
</tr>
<tr>
<td>Power Quality/ Harmonics</td>
<td>Suppress system harmonics</td>
<td>Contributes to power quality</td>
<td>Both</td>
</tr>
<tr>
<td>Black-start</td>
<td>Support system during system restoration</td>
<td>Contributes to system black-start capability</td>
<td>Both</td>
</tr>
<tr>
<td>Voltage Regulation</td>
<td>Manage delivery of reactive power to maintain voltage</td>
<td>Reduces need for new reactive power sources</td>
<td>Both</td>
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Intelligent energy dispatching systems have been implemented in the power grid for control and data access.

Some of the technologies that are nowadays integral part of modern grid systems include:

- Wide area measurement systems
- Grid condition monitoring systems
- Distribution automation systems
- Mobile operational applications for condition-based maintenance
- Advanced metering infrastructure
- Geographic Information Systems
THE NEED FOR STANDARDS

- Interconnected grid systems are fully integrated with Information and Communication Technologies (ICT) in order to allow information exchange between various data centers and to controlling grid assets.

- Standards and protocols should be defined and enforced such that grid operators from various regions maintain the same nomenclatures and terminologies.

- Industrial Control Network (ICN) standards and protocols:
  - NERC-CIP
  - ISO/IEC 27002:2005
  - NRC Regulation 5.71
  - NIST SP 800-82
- Modern electrical grid systems embody all the characteristics of a distributed network
- Ubiquitous information exchange and better awareness of energy availability and load profiles are essential
Cyber-physical systems extending from generation to consumption and facilitating the integration of distributed storage
Interoperability

- Interoperability addresses the open architecture of technologies and their software systems to allow their interaction with other systems and technologies
- Interoperability is often hampered by the differences in the data types, communication protocols, and middleware technologies used by the components involved

Deloitte, 2015
Standards ensure operation and maintenance of the system and associated equipment is improved, with greater efficiency, safety and reliability.

Standards are designed to ensure systems are safe to implement and operate, reliable, easy to troubleshoot, and efficient.

Communication is key for Energy Storage to function within the Smart Grid.

- Protocols, data models and semantic information models must be available to make full use of the potential benefit of Energy Storage.
- Communication must be available for the whole chain, power grid, power electronics, battery management (BMS), battery modules and cells.
CONCLUSION

- No known document/website/publication that defines the cooperation between the power pools
- Technical planning of African grid interconnection should be properly carried out
- Conduct modeling/simulation studies at regional levels to assess the effects of distributed storage/generation on the grid
- Conduct modeling/simulation studies to assess the interplay between the various power pools
CONCLUSION

- Interconnecting and efficiently operating the African interregional grid seems to be a challenging task: the scattered pattern of power stations and the wide spread area covered by the grid cause problems of load and frequency control.

- Interconnected power systems require a high degree of technical compatibility and operational coordination, which grows in cost, risks and complexity with the scale and inherent differences of the systems involved.

- The African regional power pools should work together to follow the same standards for the electrical grid in order to ensure a seamless interconnection and interoperation.