Microgrids: Rural and Off-Grid Electrification

3rd Africa Smart Grid Forum

Sherwin Harris
Energy Storage, Microgrid Energy Solutions, Digital Grid Leader – SSA
GE Power

October 2018
## Africa Electrification Challenge

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (billion)</td>
<td>1</td>
</tr>
<tr>
<td>Population growth rate (annual)</td>
<td>2.7%</td>
</tr>
<tr>
<td>GDP annual growth rate</td>
<td>5.4%</td>
</tr>
<tr>
<td>Rural population average growth rate (annual)</td>
<td>1.9%</td>
</tr>
<tr>
<td>Average rural electrification rate</td>
<td>14%</td>
</tr>
<tr>
<td>Electric power consumption per capita per year (kwh)</td>
<td>488 for all SSA 153 excluding South Africa</td>
</tr>
<tr>
<td>Transmission &amp; Distribution losses (% of output)</td>
<td>12%</td>
</tr>
</tbody>
</table>
DECARBONIZATION

By 2040, RENEWABLES will represent 30% of global net electricity ... or more?

IMPACT
- Generation is becoming difficult to forecast & variable
- Grid stability, Congestion Volatility on electricity markets

DIGITIZATION

GROWING THE NUMBER of connected devices & smart sensors

IMPACT
- Allowing decision making based on dynamic and nodal prices

DECENTRALIZATION

GROWING PENETRATION of distributed resources (renewable, storage, efficient devices)

IMPACT
- End user becomes an active actor of the power system ('pro-suser')
- Growing complexity of distribution grids

ELECTRIFICATION

ELECTRIFICATION OF ENERGY USES, transport (EVs) and heating

IMPACT
- Growth of Electricity demand, and an acceleration of decentralization of the power sector

TRENDS DISRUPTING THE POWER SECTOR FROM GENERATION TO T&D

November 14, 2018
Electrifying Africa: A two-pronged strategy

• About 86% of the rural population but also 37% of the urban population have no electricity access.

• To reach universal access to electricity by 2030 through power infrastructure investment, an estimated $19.1 billion would be required per year.

• This level of investment is highly unlikely; it is more likely that electrification will occur progressively through the establishment of bankable business cases for distributed microgrids combined with investments in central grid infrastructure.
What is a MicroGrid?

Integrated energy system and control + Distributed Energy Sources (DG, DS) + Loads =

Microgrid
A Microgrid is an integrated energy system consisting of interconnected loads and distributed energy resources which can operate in parallel with the grid or in an intentional islanded mode.

Key Characteristics
✓ Provides sufficient and continuous energy to a significant portion of the served load
✓ Possesses independent controls and can island and reconnect
✓ Seen as a single “Point of Control” from the grid system operator.
✓ Enables flexible power delivery system configuration and operation
✓ Enables optimization of a large network of load, local Distributed Energy Resources and the broader power system.
Microgrid Segments
Microgrids rising interest for end-users & market players

The combination of ICTs and various distributed energy resources (DER) — including DG, DS, EVs, and DR — will allow the creation and proliferation of new distributed energy systems (DES)

Source: MIT utility of the Future Study

Before: Microgrids as safeguards in specific areas

Provides reliable, continuous power for critical loads like in hospitals or smelters factories

Improvement in the cost and performance of a range of DG

Potential breakthroughs in distributed energy storage

Changing uses and use patterns of electricity (EV, DR...)

Growing expectation on Grid resiliency (Vs weather conditions....)

Ahead: Microgrids is seen as new way of operating the network

Combines local DERs, including DG, DS, and/or DR, to enable a business model that provides valued services to energy end users or upstream electricity market actors.
Microgrid Business Models

Owners of Power Generation and Distribution Assets

<table>
<thead>
<tr>
<th>Utility Model</th>
<th>Hybrid Model</th>
<th>Private Model (Unregulated)</th>
<th>Private Model (Regulated)</th>
<th>Community Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility</td>
<td>Private/Utility/Community</td>
<td>Private</td>
<td>Private</td>
<td>Community</td>
</tr>
</tbody>
</table>

Brief Description

- Government or parastatal utility manages all aspects of microgrid
- Private players generate and utility distributes electricity (or the reverse), or private entity to commercialises electricity generated by and distributed through public assets
- Private company manages all aspects in the absence of government regulation
- Private company manages all aspects in a regulated environment
- Community members organise to manage generation and distribution in a regulated environment, with support and/or coordination from an NGO or private company

Pros

- Can absorb funds easily
- Less regulation needed
- Connection of microgrid to central grid can be easier
- Cross-subsidisation or tariffs, thus affordability easier ensured
- Aim to fulfil national electrification targets
- Different actors contribute their strengths and technical and management know-how
- Scalable, profitable
- Less conflict potential with customers in case of distribution by utility with cross-subsidised tariffs
- Commercial sustainability for long-term operation
- Ability to act fast without government interference
- Profitability ideally allows for scaling up of operations
- Scalability through private capital
- Technical know-how, high reliability
- Profitability ideally allows scaling up operations
- Legal security of regulated market attracts private finance
- Self-managed public infrastructure
- Less conflict potential with customers and officials
- Creating assets and local ownership
- Enabling self-determination and economic development

Cons

- Not the core business
- Unsuitable company structure for smaller projects
- Strain on limited budget
- Political interference
- Possibility of corruption in procurement
- Complex management, feasibility of models depend on regional/local context/structures
- Non-fulfilment of contracts due to conflicts between business partners
- Insolvency of one partner puts full operator model at risk
- No financial support from public obtainable
- Grid-interconnection challenging/impossible
- Changes in regulation and fixed tariffs can reduce profitability
- Conflicts with customers due to monopoly
- Insufficient quality and safety risks of service can occur if it is not supervised, which can contribute to a bad image of microgrids
- Reliable regulation needed, dependency on lengthy approval procedures
- Debt financing needed for scaling up
- Vulnerable to changes in regulation, fixed tariffs, conflict with customers
- High transaction costs
- Potential risk: grid interconnections
- Insufficient local human capacity (technical, managerial)
- Often unclear ownership structure
- Usually high grants needed
- Tariffs not covering operation and maintenance and reinvestment costs
- Corruption risk due to overlapping of management and social and family connections

Source: EUEI; Frost & Sullivan
Headwinds & tailwinds of microgrid development

**Tailwinds**

- **Donor initiatives** like *Sustainable Energy for All* to provide potential funding and development partnership.
- **Significant cost requirements to extend the central grid**
- Increased focus on *renewables*
- Microgrids provide *reliable power* to combat existing issues of poor quality, shortages and inefficiency
- Government plans & policies of industrialization will require reliable supply of high-quality power.
- **Technological improvement** & increased efficiency leading to lower cost of production and operation of microgrids
- **Decentralized power & storage** will help in stabilising existing grid infrastructure

**Headwinds**

- **Lack of clear regulation**: Without a clear regulation to ensure common protocols and specifications for microgrid operation, acceptance of microgrids by governments and utilities is expected to be limited due to the potential risks they present to grid security.
- **Availability of funding**: Lack of clear policy presents a restraint in investment. Resulting tariffs are uncompetitive to central grid tariffs and may require subsidization.
- **Limited proof points**: While many markets show a significant need for microgrid development, there is limited applied knowledge on proven development and operating models.
Existing microgrid projects in SSA

- **South Africa**: Several rooftop installations – ABB Factory, Mall of Africa, ABSA
  - 5kW Wind System

- **Nigeria**: Several 1-7kW Solar PV systems, 6 solar mini grids
  - 5kW Wind System

- **Kenya**: 18 operational microgrids (50-500kW, solar/wind) owned by Kenya Power
  - 2 Solar PV microgrids privately owned
  - 4 Microgrid projects managed by Power hive

- **Zambia**: 1 DC Microgrid, 0.78kW
  - 24kW Solar PV with storage – Sioma High School

- **Tanzania**: Solar – Lake Eyasi, 13 diesel minigrids (TANESCO)

- **Cape Verde**: Planned solar PV 27.3kW

- **Equatorial Guinea**: 5MW installation planned – GE/Princeton Power Systems Inc. / MAECI Solar

- **Senegal**: 5kWp Solar PV -diesel

- **Mali**: 231kWp

- **Mauritania**: 15-20kWp Solar PV -diesel

- **Uganda**: 5kWp Solar PV - diesel

Source: Development of microgrid in SSA, IRENA
Example in SSA – Standerton Vikinduku Engineering & Projects

**IKHAYA SOLAR HOME RDP Solution**

1. Ikhaya Solar PV
   - 100Wp for Rural Households
   - 300Wp for Urban and Semi-Urban Household

2. Ikhaya Solar Water geyser
   - 100L Geyser
   - Flat-bed type, cannot be damaged by hail

3. LED Lighting Included
   - Energy Efficient LED Lighting X 8 lites
   - Lasts more than 5 years

4. Energy Efficient Appliance (OPTIONAL)
   - Energy Efficient DC Flat-screen TV
   - Energy Efficient DSTV DC Decoder
   - Energy Efficient 3-Speed Table Fan
   - Energy Efficient Small Family Fridge

5. Solar PV Street Light (OPTIONAL)
   - LED Street Light that uses power from the sun

**STANDERTON RDP PROJECT: Houses Pics**

[Images of houses and solar panels]
Main objectives:
- Energy surety, Back-up & service quality.
- Reduce Outages impact on Grid.
- Optimal use of DER.

Highlights:
- Seamless transition interconnected/islanded mode of operation;
- Stable operation in islanded mode (V, F control)
- Adaptative protection schemes
- Critical load supply control
- Optimal DER (PV) operation in interconnected mode

Solution:
- Automation
  - MG AFBs embedded in DAP server, IEC61850 system with Micom IEDs, C264
- Analytics
  - Simulation forecast & dispatch, e-terraDistribution
Main objectives:
Develop Microgrid Power Mix optimization and management application with NTU for Semakau Island and NTU ecocampus

Highlights:
- Optimal RT automated DER
  Maximization of RES penetration with reduced operational losses and cost.
- Improvement of system observability (RT Local State Estimation).
- Strong/weak grid-connected mode.
- Field installation in 2 sites Ecocampus and Semakau island

Solution:
Automation
- MG AFBs embedded in DAP server, IEC61850 system with Micom IEDs, C264
Main objectives:

- Energy surety and Back-up & service quality
- Reduce Outages impact on Grid
- Optimal use of DER

Highlights:

- To operate in both grid-connected and islanded modes.
- In grid-connected mode, optimally utilize battery storage, and solar to reduce energy and demand charges.
- In Islanded mode provide, uninterrupted power to the critical loads and reliable power to pre-determined supported loads through the CHP
- In case of grid failure, provide power to critical loads with a seamless transition

Solution:

Automation

- MicroGrid-EMS in D400 and DNP 3 IEDs system for Optimal dispatch.
Main objectives:

- Optimal use of DER (mostly PV)
- Planned and unplanned islanding operations
- Active customer participation to grid balancing

Highlights:

- To operate in both grid-connected and islanded modes.
- In grid-connected mode, optimally utilize battery storage, and solar to balance grid and minimize losses
- In Islanded mode provide, uninterrupted power running on local PV and storage

Solution:

1. NEM is the energy management platform that manages the smart solar district
2. MCU: is the master field control unit that supervise and manage a part of the network (Microgrid).
3. FCU is an intelligent gateway between the MCU and DER. It can supervise the DER and handle simple control functions
Thank You