Lessons Learnt from a Storage Based Microgrid Application

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Senior Application Leader, Microgrid Energy Systems, Eaton
Agenda
• Brief introduction to Eaton
• Power Challenges in Africa
• Wadeville Case Study
• Business Case for Storage
• Role of Standards
Our **vision** is to improve the quality of life and the environment through the use of power management technologies and services.
Get to know our business.

**Electrical Sector**
- 2018 Sales $13.1 B
  - Electrical Products
  - Electrical Systems & Services

**Industrial Sector**
- 2018 Sales $8.5 B
  - Aerospace
  - Hydraulics
  - Filtration
  - Vehicle
  - eMobility

Total sales $21.6 Billion USD
Net income $2.2 Billion USD

- Headquarters: Dublin, Ireland
- Chairman & CEO – Craig Arnold
- Key locations in Cleveland, United States; Shanghai, China; Morges, Switzerland; São Paulo, Brazil
- Regional engineering teams to support products and custom solutions
- Customers in more than 175 countries
- Approximately 99,000 employees
Eaton’s solid presence in Africa

Dedicated diverse team
- **700** employees
- More than 100 distributors throughout Africa
- **5** offices across the continent
- **2** service hubs
- Engineering Services
  - Study | Design | Build | Support

Regional manufacturing capability
- **200k ft²** of manufacturing space in South Africa and Morocco
- Africa based engineering services
- BBBEE Level 1 certification

A broad portfolio supplemented by “made for Africa” products and services
- IEC and UL approved products
- Historical brands in Africa since **1927**
- Local manufacturing & engineering of Low Voltage, Medium Voltage and Power Quality products built for Africa

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A portfolio designed to meet your power management needs.
## Low Access and Reliability

<table>
<thead>
<tr>
<th>Country</th>
<th>Electricity access %</th>
<th>Avg outage hours/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Côte d’Ivoire</td>
<td>61.9</td>
<td>230</td>
</tr>
<tr>
<td>DR Congo</td>
<td>13.5</td>
<td>830</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>27.2</td>
<td>570</td>
</tr>
<tr>
<td>Ghana</td>
<td>78.3</td>
<td>790</td>
</tr>
<tr>
<td><strong>Kenya</strong></td>
<td><em>36</em></td>
<td><em>420</em></td>
</tr>
<tr>
<td>Mozambique</td>
<td>21.9</td>
<td>80</td>
</tr>
<tr>
<td>Niger</td>
<td>15</td>
<td>1,400</td>
</tr>
<tr>
<td>Nigeria</td>
<td>56.4</td>
<td>4,600</td>
</tr>
<tr>
<td><strong>Senegal</strong></td>
<td><em>61</em></td>
<td><em>130</em></td>
</tr>
<tr>
<td>South Africa</td>
<td>86</td>
<td>50</td>
</tr>
<tr>
<td>Tanzania</td>
<td>18.9</td>
<td>670</td>
</tr>
<tr>
<td>Zambia</td>
<td>27.9</td>
<td>180</td>
</tr>
</tbody>
</table>

Source: https://qz.com/africa/1431213/africas-electricity-shortages-have-health-and-economic-costs/
Global Energy Access

National electrification rates globally

Source: IHS Markit, World Bank, International Energy Agency (IEA/1706244)

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Rising Costs of Electricity

Trend in Average Electricity Prices realised by Eskom per kWh (1973 to 2015/16)

Source: Deloitte Analysis, Eskom data and 2011 annual report
Note: In 2004/5 Eskom change financial year from calendar year (year-ending 31 December) to year-ending 31 March
Evolving Power Sector Landscape:

Historical Typical Power Grid

- Generation: Few Base Load Sources
- Transmission
- Distribution
- Customers

One Way Power Flow

Decentralized Grid

Power Flows in Many Directions

- Fossil Fuel - generator
- Solar PV - generator
- Wind - generator
- Battery - storage

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Intro to Microgrids
What is a Microgrid?

Microgrids are stand-alone power generation, distribution and storage systems that work with or independently from the main utility grid to help businesses, campuses and communities to:

- Maintain reliable supply of power
- Reduce operating costs
- Optimize energy usage
- Reduce carbon emissions
Benefits of a Microgrid

- **Decrease costs**
  - Help avoid peak charges
  - Reduce the reliance on expensive fuels like diesel
  - Eliminate costs associated with unexpected power loss or load shaving

- **Increase Reliability**
  - Give continuity of supply
  - Enable grid stability and efficiency

- **Reduce CO2**
  - Facilitate the wider adoption and deployment of renewable power generation

- **Increase autonomy**
  - Effectively manage power and generation assets to meet your sites individual needs
Why not solar alone?

<table>
<thead>
<tr>
<th>Microgrids</th>
<th>VS</th>
<th>Solar Alone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy dispatchable</td>
<td>Renewables are intermittent, not dispatchable</td>
<td></td>
</tr>
<tr>
<td>Excess solar stored for later use – and keeps solar on even when grid goes off.</td>
<td>Excess solar curtailed by rule or when grid goes out</td>
<td></td>
</tr>
<tr>
<td>Configurable for many load profiles</td>
<td>Load profile must track sun to capture value</td>
<td></td>
</tr>
</tbody>
</table>

**Diagram:**

- **Solar self-consumption without energy storage**
  - Morning: Energy consumption, PV production, and self-consumption.
  - Evening: Energy consumption and self-consumption.

- **Solar self-consumption with energy storage**
  - Morning: Energy consumption and PV production.
  - Evening: Energy consumption and self-consumption with a stored energy buffer.
Case Study
Wadeville South Africa Microgrid
Key Challenges at Eaton’s Wadeville facility:

Due to ageing infrastructure we experienced increased in load shedding due to:

- Cable faults
- Scheduled maintenance of the grid

As a manufacturing facility we faced:

- Increase energy charges impacted by seasonality and peak time
- Network demand charges
Business Case for Wadeville Plant

Three main use cases enabled by storage:

- **Peak Shaving**
  - Reduce demand / peak charges
  - Maintain constant demand day or night

- **Integrated PV**
  - Reduced PV variation with energy storage system
  - Reduce utility demand

- **Islanding**
  - Continuous operation of manufacturing regardless of utility supply
  - Minimize backup fuel consumption

Reduced Energy Charges

Improved overall power quality

Mission critical operation uninterrupted
Key Hardware Components of the Wadeville Microgrid

Sources
- Utility
- 400 kVA Generator
- 200 kW Photovoltaic
- 275 kW Battery Storage (200 kWh)

Loads
- 50 – 375 kVA (30 min readings)
- 70 kW compressor

Use Cases (partial list)
- Peak Power Limiting / Load Leveling
- Renewable Firming
- Load Shifting
- Resiliency: Islanded operation optimizing renewables

Loads
50 – 375 kVA (30 min avg.)
Value Stream 1: Tariff Optimization – Max Demand Reduction
Reduces Maximum Demand Charges

Peak Demand Reduced by 26% Today
Value Stream 2: Tariff Optimization – Energy Arbitrage
Reduce Grid Consumption when Costs are Highest

Charge at R1.03 ($0.07) rate

Discharge during Peak Period R6.10 ($0.41) for net benefit of R5.19 ($0.34) per kWh
**Value Stream 2: Tariff Optimization – Energy Arbitrage**
Reduce Grid Consumption when Costs are Highest

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Summer Morning Peak</th>
<th>Summer Evening Peak</th>
<th>Winter Morning Peak</th>
<th>Winter Evening Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summer</strong></td>
<td>R0.91 ($0.06)</td>
<td>R1.86 ($0.13)</td>
<td>R1.22 ($0.08)</td>
<td>R1.86 ($0.13)</td>
</tr>
<tr>
<td><strong>Winter</strong></td>
<td>R1.03 ($0.07)</td>
<td>R6.10 ($0.41)</td>
<td>R1.75 ($0.12)</td>
<td>R6.10 ($0.41)</td>
</tr>
</tbody>
</table>

- **Peak**
- **Off Peak**
- **Standard**

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Value Stream 3: Renewable Maximization
Solar PV and Storage Reduce Total Grid Consumption

Net Total Savings Today = R2,401.55
Value Stream 3: Renewable Maximization
Storing Excess Solar
Value Stream 4: Outage Avoidance
Eliminate Production Losses Due to Power Outages

Continuous power provided during 2 hour utility outage, avoiding a R97,200 loss in production
Combining the value streams over 12 months leads to significant savings (Wadeville Microgrid generates 56% Operational Savings)

- Electricity bill reduction of 30% total:
  - 32.4% Standard
  - 36.9% Peak
  - 5.2% Off Peak
  - 36.4% Max Demand
- Diesel cost reduced 26%
- Losses due to power cut eliminated:
  - Uptime Savings: 1,298,100 ZAR*
- Environmental impacts:
  - RE fraction 18.7%
  - 11,812 Metric Tons CO2 reduced
*Based on 33 outage hours over 12 months that directly impacted production (M-R 7:30am-4:30pm; F 7:30am-1pm)

Multiple value streams stacked to reach a high ROI, and breakeven expected in less than 5 years
Role of Standards
Microgrid & Storage Standards & Guidelines

Standards play a key role in the design, installation, and operation of Microgrids and Embedded Generation Systems

- IEEE 2030.7; 2030.8
- IEEE 1547.3; 1547.4
- IEC 62933: 1 - 5
- SANS 10142 & NRS 097
Implications of Limited Standards in Storage

- Difficulty for customers to align needs with suitable battery technology for application
- Challenges with regulation and compliance
- Push for commoditization of energy storage systems based on price not function
Conclusion: We Need Consensus on Standards

- Ensure consistency
  - Quality assurance
  - Safety
- Increase consumer and utility confidence
- Assess different energy storage offerings against a common benchmark