Death and Rebirth in the Power Sector: Why Africa Should Fascinate the Energy Educator and Researcher

Carnegie Mellon Electricity Industry Center Series: Jan 29th, 2020, Baker Hall 129

Dr Barry Rawn
Associate Teaching Professor, CMU Africa
Visit two “book-end” jurisdictions in Africa: big changes happening:

**educator:** rediscover and illustrate fundamentals

**researcher:** technical interest alone: in the now, not the future.
NOW

developed power systems
- Demand response shapes load to match renewables
- “Prosumers” and the utility death spiral
- Self-healing resilient grids from distributed resources
developing power systems

developed power systems

optimally used systems operated close to limit new cost tradeoffs

FUTURE

NOW
NOW

developed power systems

developing power systems

stressed systems
operated beyond the limit
different cost tradeoffs
Future arrives early for energy storage, coupled microgrids.
NIGERIA: big change due to scale

Where the utility death spiral already happened..

educator: non-uniform reliability tariff design

researcher: 3rd party compliance monitoring
>10 GW of off-grid demand met by diesel gensets in banks, hotels, businesses, homes: turning solar.
Abuja:
Housing development with tri-source battery charging: solar, grid, diesel;
storage batteries, stabilisers common in many homes

Lagos:
Distribution companies perform continual load shedding to follow supply

Context sets feasibility of technology solutions
Distribution investments, some of them from before 1951, had started to decay. The population and areas served by the ECN had grown enormously, but the radial distribution systems lacked the design necessary to cope with load growth. Apart from the introduction of ‘Ring Main Units’ the ECN had added no new feature to its distribution techniques. Substandard assets had started to creep into the system. A quick example is the wood pole to support conductors.

The Corporation had no ‘Customer Service Policy’ except for scanty statutory provisions at the back of ‘Application Form ECN 74’. After operating for more than two decades, several issues for which operatives needed the same answers throughout the country had arisen, but the ECN had left operatives on their own to provide whatever answers they wanted and the ECN customers did not have the benefit of uniform treatment. Some of these issues had to do with revenue and I hasten to say that the Corporation’s best years of revenue performance were 1961 and 1965 when it achieved 6.4% and 7.3% *rate of return*, which were still lower than the 8% expected return.

Adequacy in a 1208MW system already a problem.
NIGERIA:

1972-1990

Military dictatorship

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Tariff design punished large consumers, customers charged for meters

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<td>Industrial</td>
<td>347</td>
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<td>192.2</td>
<td>532.4</td>
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<td>Total</td>
<td>597.6</td>
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Adapted from Margaret Peil, Lagos: The City is the People, London: Belhaven Press, 1991, p. 185, Table 8.3
Customer Attitudes and House to House Reliability

Reaction to outages, preferences for power allocation

Survey Responses
1036 responses

Survey Workers
20 survey workers

Survey Questions
58 survey questions

Total Answers
45305 answers
### NIGERIA:

**1972-1990**

*Military dictatorship*

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“This had grave social and economic consequences. Many artisanal or small scale enterprises depend on a regular power supply. A large number of these have been forced to fold up. In this category are the barbing/hairdressing, tailoring or fashion designing, welding, panel-beating, electrical and electronics repair enterprises. Not only were the proprietors, employees and apprentices engaged in these enterprises thrown into the labour market, some have taken to crime in desperation. The spate of violent robberies in the late 1990s derived from the high rate of unemployment generated by power shortages.”

*Infrastructure Development and Urban Facilities in Lagos, 1861-2000 — Ayodeji Olukoju*
NIGERIA: rebirth from enterprises that already left the grid (e.g. banks, factories)?
NIGERIA: in the meantime..

Supply demand balance short term challenge

Voltage

SOUTH AFRICA
NIGERIA
EUROPE

Frequency

SOUTH AFRICA
NIGERIA
EUROPE
NIGERIA: in the meantime..

..due to non compliance.
System Collapse: June 27th, 2017
NIGERIA: in the meantime..

Circular Debt:
• Continuing privatization process
• Generators don’t always comply to provide ancillary services
• Not currently monitored or regularly verified

Frequent System Collapses:
• Limited situational awareness
• Monthly restoration from complete blackout

*Killer App #1*
*Online monitoring of generator compliance*

*Killer App #2*
*Automatic Islanding and resynchronisation*

*Non-compliance common and consequential in Nigeria; as is need for restoration*
NIGERIA: in the meantime..

Killer App #1
Online monitoring of generator compliance

Killer App #2
Automatic Islanding and resynchronisation
Improving the Operation and Restoration of the Nigerian HV Grid

Research questions
- Can acceptable operating points be found, even for large cross-country flow, ambitious delivery?
- How feasible are alternate restoration pathways after system collapse and blackout?

Prof Larry Pileggi
ECE

Aayushya Agrawal
PhD Candidate, ECE

Graph showing the number of generators versus generator voltages [p.u.] with two categories: Base Generator Voltages and Re-Dispatch Generator Voltages.
NIGERIA: big change due to scale

Slow change means contributions needed to manage system as is..

educator: non-uniform reliability tariff design

researcher: 3rd party compliance monitoring
RWANDA: big change due to pace..

100% motorcycle fleet electrification mandated, 100% access forecast, in next five years.

educator: cross-subsidies

researcher: energy-water nexus
RWANDA:
rapid pace due to size,
social organization

GIS mapping
In distribution planning

Image credit: Kobus Van Zyl, Rwanda Energy Group
RWANDA:
Off-grid zones open to developers, grid encroachment rules already drafted.

48% by solar decentralized (productized service)

52% by centralized (subsidized grid extension)
What can we learn about stimulation of electricity demand, and energy transport?

Rockefeller funded Electricity Growth and Use in Developing Countries

Electric Circus

e-guide

Harnessing the power of data to end energy poverty

e-bike, Kenya
Economic improvement through electrification

• How can sustainable irrigation and cold-store capacity be co-planned?
• What new models for energy distribution and mobility are possible through electric vehicles?
• What are the barriers and possible incentives?

Regulatory questions:

• How to balance commercial and industrial self-generation using solar against utility viability?
• What should goals for cross subsidies be?

..engage directly with on-going or upcoming research

How to work with CMU Africa in Rwanda?
Leveraging electricity infrastructure to improve agricultural productivity in East Africa

Jorge Izar, Nathan Williams, Paulina Jaramillo

Paulina Jaramillo
CMU, EP

Nathan Williams
RIT

Research questions

• Where are there opportunities for co-investment in electrical and small-scale irrigation infrastructure in Rwanda?
• What is the potential for electricity consumption and yield increases from small scale irrigation in Rwanda?
• What other factors limit returns on electricity-irrigation investment?
Tapping Solar E-Waste Streams for Second-Use Battery Storage

B. Rawn, D. Ross, Katrina Ramirez-Meyers, S. Tennakoon, J. Whitacre

Research questions

• What is the statistical distribution of remaining capacity found in LiFePo cells in solar home system battery modules?
• What might be easily measureable and useful predictors of cell quality?
• What barriers may exist to more local manufacture and supply of energy storage services?
How to work with CMU Africa:

Visit CMU-Africa

• Give a distinguished lecture
• Meet with local stakeholders

Spend a semester in Kigali

• Teach 1-2 courses
• Co-advice independent studies by CMU-Africa students
• Meet your CMU-Africa colleagues

Develop a research proposal in collaboration with the KCRC

Take a trip on the pathway to impact.
Understand just one limit of technology:

Isolated specialty work:

Join us in broad, fundamental applied, urgent work:
..to compare and exchange, to re-discovering fundamentals:

Joint work from two or more contexts:

Those who understand fundamentals and context: engineers ready to re-write