Grid power quality in the Global South: status, impacts and mitigation for appliances

Full title of paper: The impact on appliances of unreliable and poor-quality public grid power in the Global South, with options for technological and policy response

Jeremy Tait, Tait Consulting GmbH

Patrick Beks, Re/Gent B.V.

With thanks also to CLASP and Efficiency for Access

Economies in the Global South struggle with unreliable and poor quality public grid power

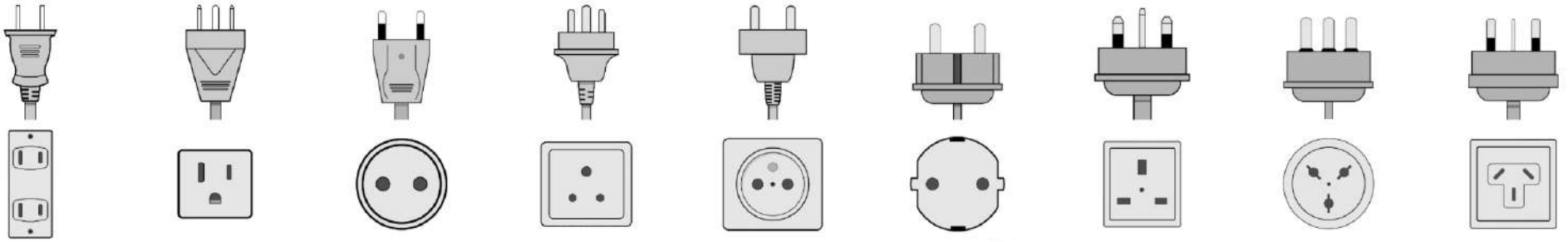


Image: https://www.iec.ch/world-plugs

The 'Global South'

- Term as used by the UN Office for South-South cooperation https://unsouthsouth.org
- The term 'developing countries' was dropped by UNCTAD in 2021.

The legacy UN listing of 181 'developing' economies includes the Caribbean, Africa, South America, Central, South and Southeast Asia, the Middle East. https://unstats.un.org/unsd/methodology/m49/

'Power Quality'

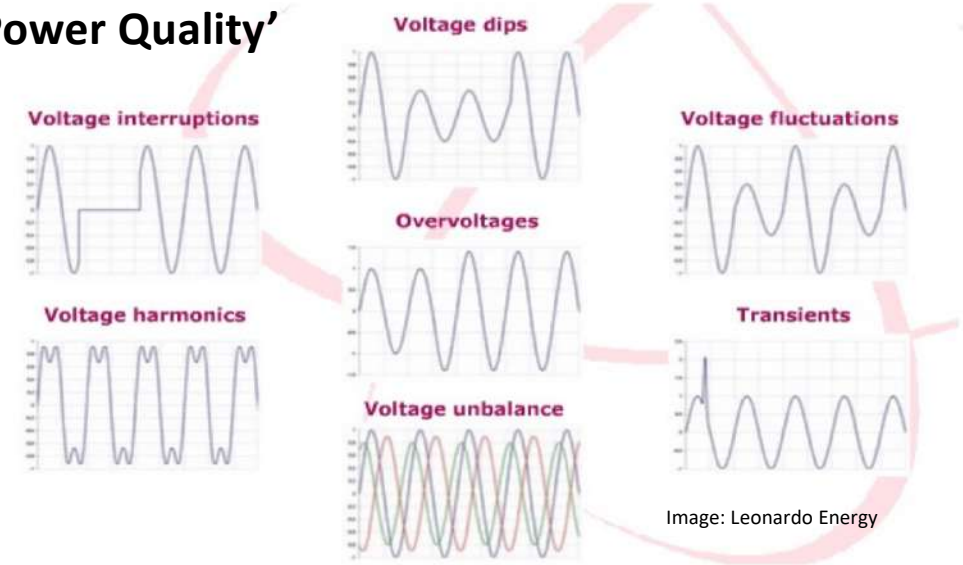
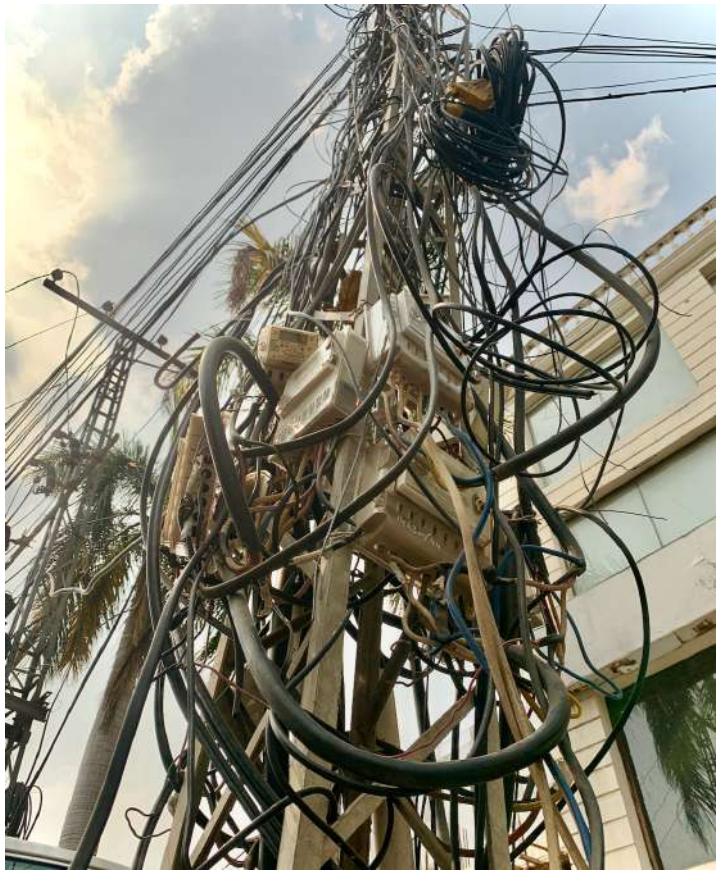


Image: Leonardo Energy

Power Quality and appliances - *Agenda*



1. What is ’the power quality problem’?
2. The scale of the problem
3. Why so serious?
4. What can be done about it?
5. Conclusions

Is having grid power a binary situation?

Grid connection

‘Recommended power quality’, defined in IEC TS 62749 or similarly in EN 50160

- <+-10% voltage magnitude variations for 95% of the week
- Supply voltage dips - majority <1sec and depth <60% of voltage
- Short (<3 min) interruptions few tens-hundreds per year with 70% <1s
- Long (>3 min) interruptions <10-50 per year

No Grid connection

Having grid power is **NOT** a binary situation

Grid connection

Example problems when public grid power does NOT meet ‘Recommended power quality’

- Voltage at 50% to 70% of nominal for most of the time
- Daily blackouts lasting hours
- Voltage spikes to 350V or even 450V on 230V nominal
- Harmonic ‘pollution’
- Frequency disruption

No Grid connection

The twighlight zone of unreliable grid

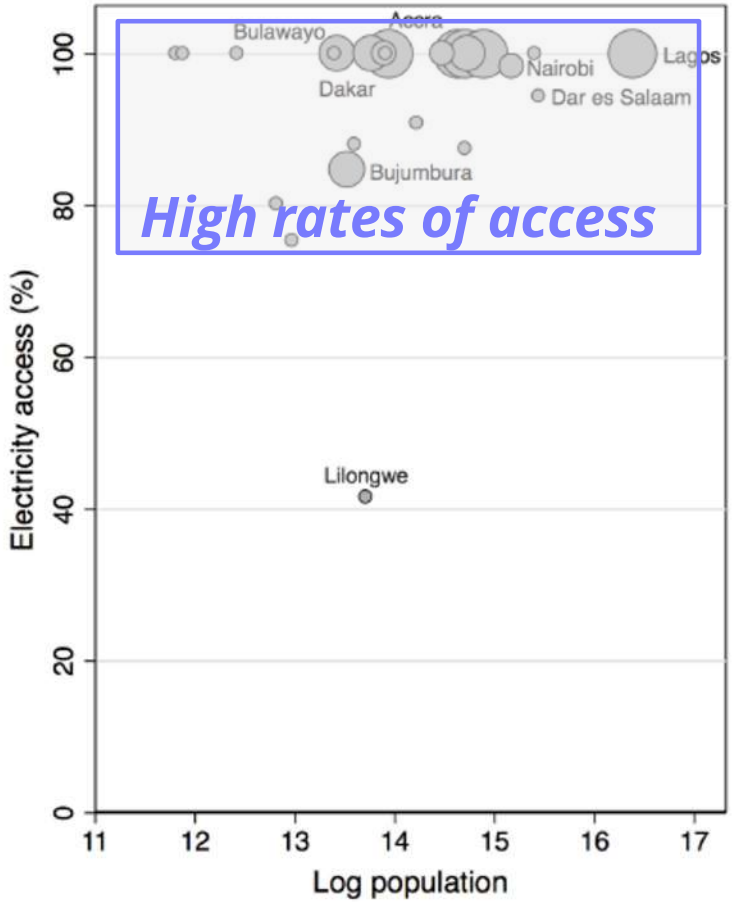
Causes of Power Quality (PQ) problems include:

- Overloaded distribution lines and transformers
  (due to rapid growth; illegal connections; under-investment; lack of foresight)
- Lack of protection equipment
  (e.g., surge arrestors) and grid management equipment
- Lack of maintenance on distribution equipment
  (stemming from lack of financial *and* staff resources)
- Poor control of EMC in end-user equipment, especially power electronics
  (which degrade power quality in the local network)
- Some theft and vandalism.

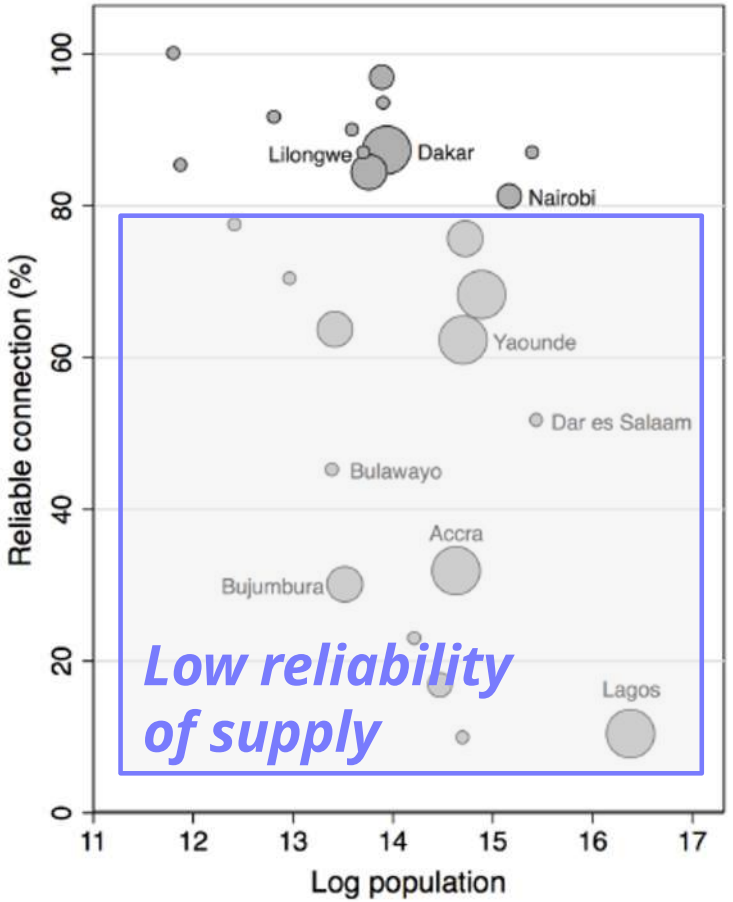
Technical answers are known and available to grid operators and utilities
– but must be paid for

Example: Many Sub-Saharan Africa connections… but poor reliability

Electricity access



Reliability*

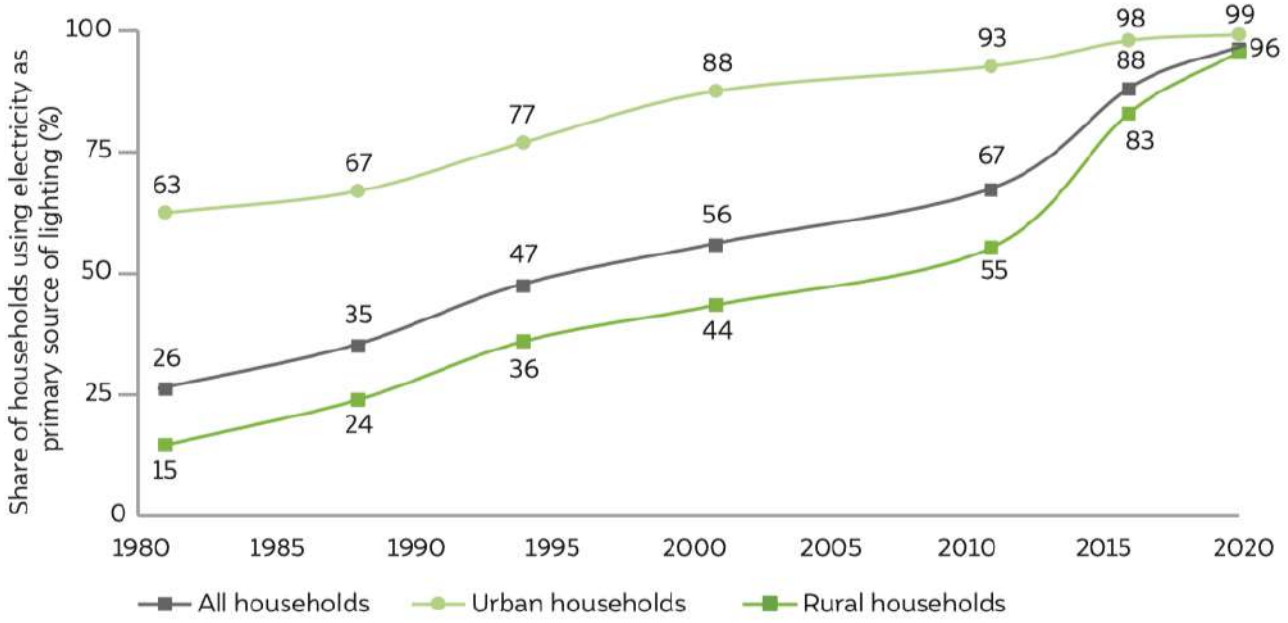


*defined as 'works all of the time or most of the time' from surveys

[Wolfram 2017; Gertler, et al.]

Example: India - champions of growing grid access

- Over two decades, government schemes brought nearly 800 million Indians out of darkness
  (CEEW IRES 2022)
- Percentage of population with connection rose from 76% in 2010 to 99% in 2020
  (World Bank data in the Economist, 2023)
- Kerosene for generators in rural India fell from 9bn litres in 2015 to 2bn in 2021, as people got access to grid
  (India Ministry of Power)



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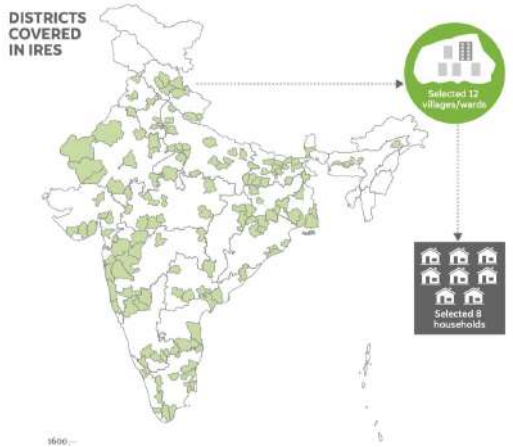
But beneath the headlines are power quality problems, as shown by India-wide survey:

- Average Indian household receives 20.6 hours of power supply per day
- Most households (76%) faced unanticipated supply interruptions.
- Two-thirds of rural and two-fifths of urban households face outages at least once a day
- One third of households faced either long blackouts, low voltages, or appliance damage in the month preceding the survey.



CEEW THE COUNCIL

Survey of >14,000 households across 21 states of India during 2019.
State of Electricity Access in India, Insights from the India Residential Energy Survey (IRES) 2020, CEEW. www.ceew.in

Example: WHO power quality challenges

- Vaccine freezers and health appliances were interrupted by blackouts; damaged or destroyed by voltage sags, voltage swells etc.
- Loss of equipment = loss of healthcare

The WHO PQS equipment certification programme had to address this

World Health Organization

PERFORMANCE QUALITY SAFETY

Example: WHO power quality challenges

WHO PQS quantified the problem:

- Monitoring for WHO of equipment in 350 health centres in Kenya and Nigeria in 2018-2021 analysed the problems faced
- Showed voltage 350V (for 220V nominal) in more than 60 of the centres on 3500 separate occasions
- 28 health centres experienced >415V
- 60 of the voltage events lasted >2 hours; one lasted >15 hours
- Detailed analysis of all power quality events

Unprotected equipment is destroyed in these situations.

WHO PQS defined answers through their certification programme:

- Performance specs for voltage stabilisers & surge protection, for a 'standard' range or for an 'extended' range of disturbance level
- Standards of performance and protection for equipment
- Ride-through testing methods for equipment

WHO / UNICEF certified appliances and equipment can:

- Continue working under typical conditions of reliability and power quality (for *operation*)
- Safely shut down and survive the worst that local grids could allow (for *protection*)

See https://apps.who.int/immunization_standards/vaccine_quality/pqs_catalogue/index.aspx

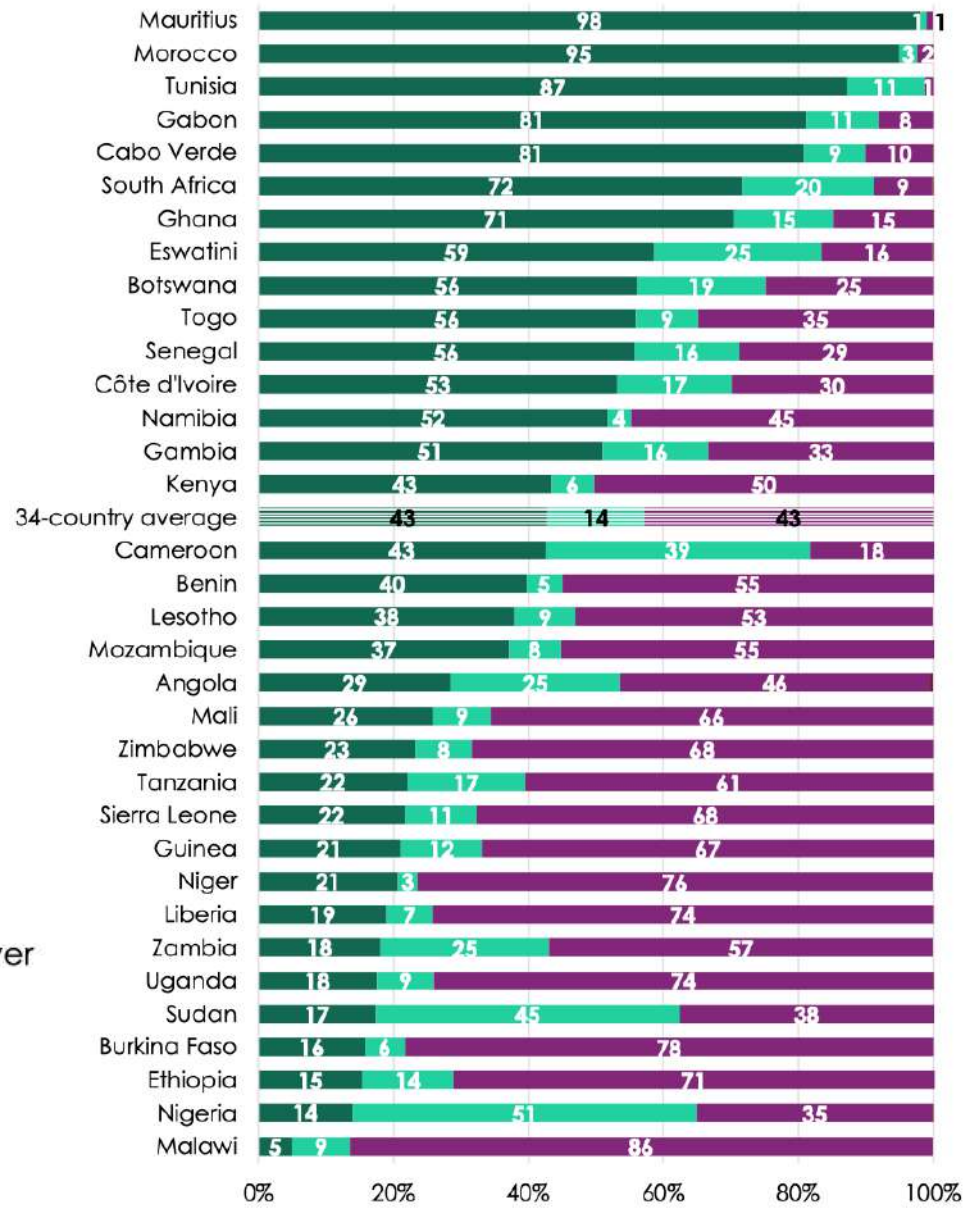
World Health Organization

PERFORMANCE QUALITY SAFETY

Unreliable grid quantified by Afrobarometer

From 48,000 nationally representative interviews across 34 African countries* by Afrobarometer.

- "Fewer than half **(43%) of Africans enjoy a dependable supply of electricity** from a national grid … rural and poor people are at a huge disadvantage" (Afrobarometer, April 2022).
- One third of citizens in Nigeria, Ethiopia and Guinea rate reliable electricity as **a critical problem for government to address** (Afrobarometer, 2019/2021).

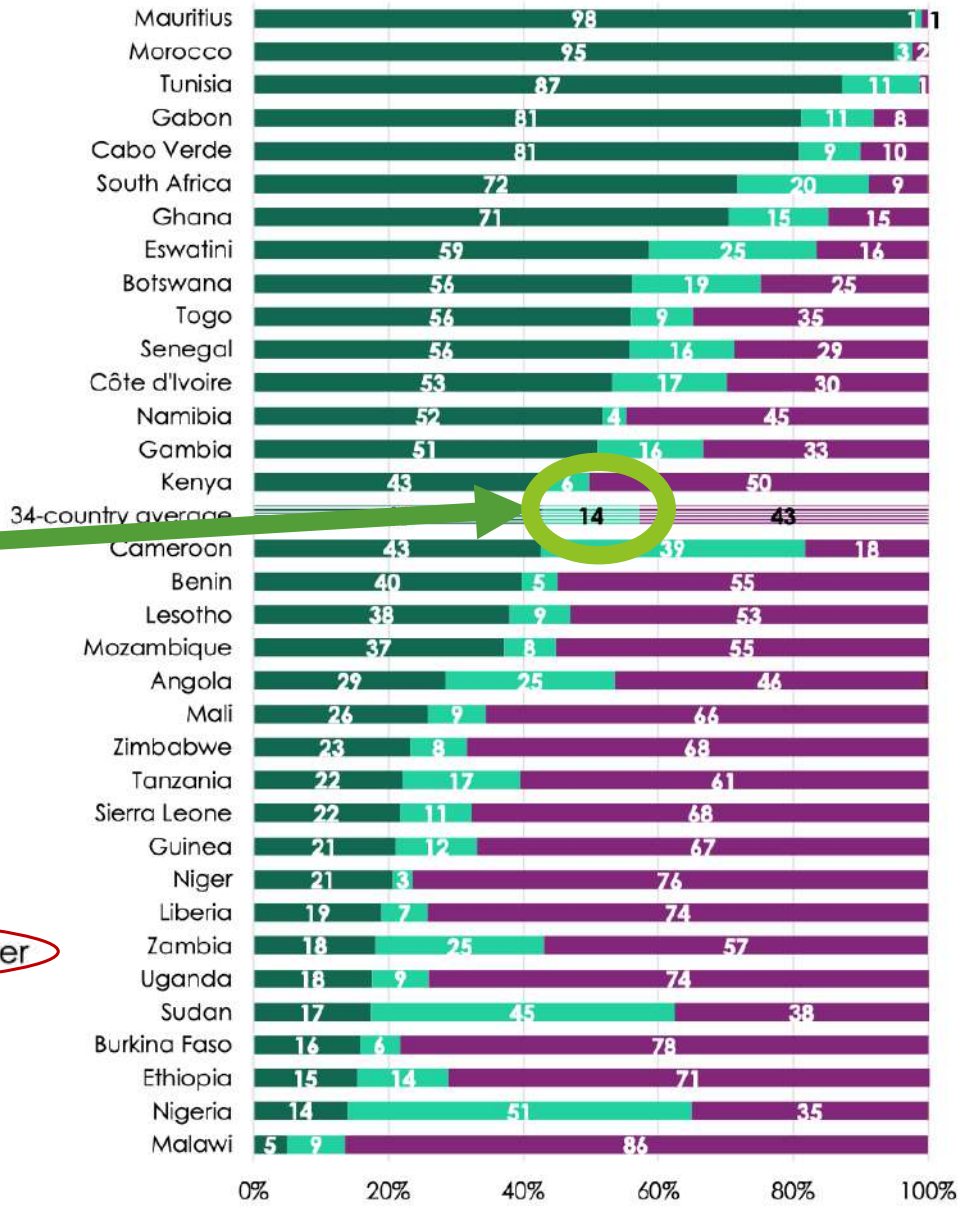


AFRO BAROMETER
Let the people have a say

*Population of the 34 countries is 921 million (72% of African population).
Dispatch 514, 8 April 2022.
www.afrobarometer.org

Unreliable grid quantified by Afrobarometer

123 million Africans across 34 countries have a connection that works ‘about half the time, occasionally or never’



- Connected, works most/all of the time
- Connected, works about half the time, occasionally, or never
- No electric grid or no connection

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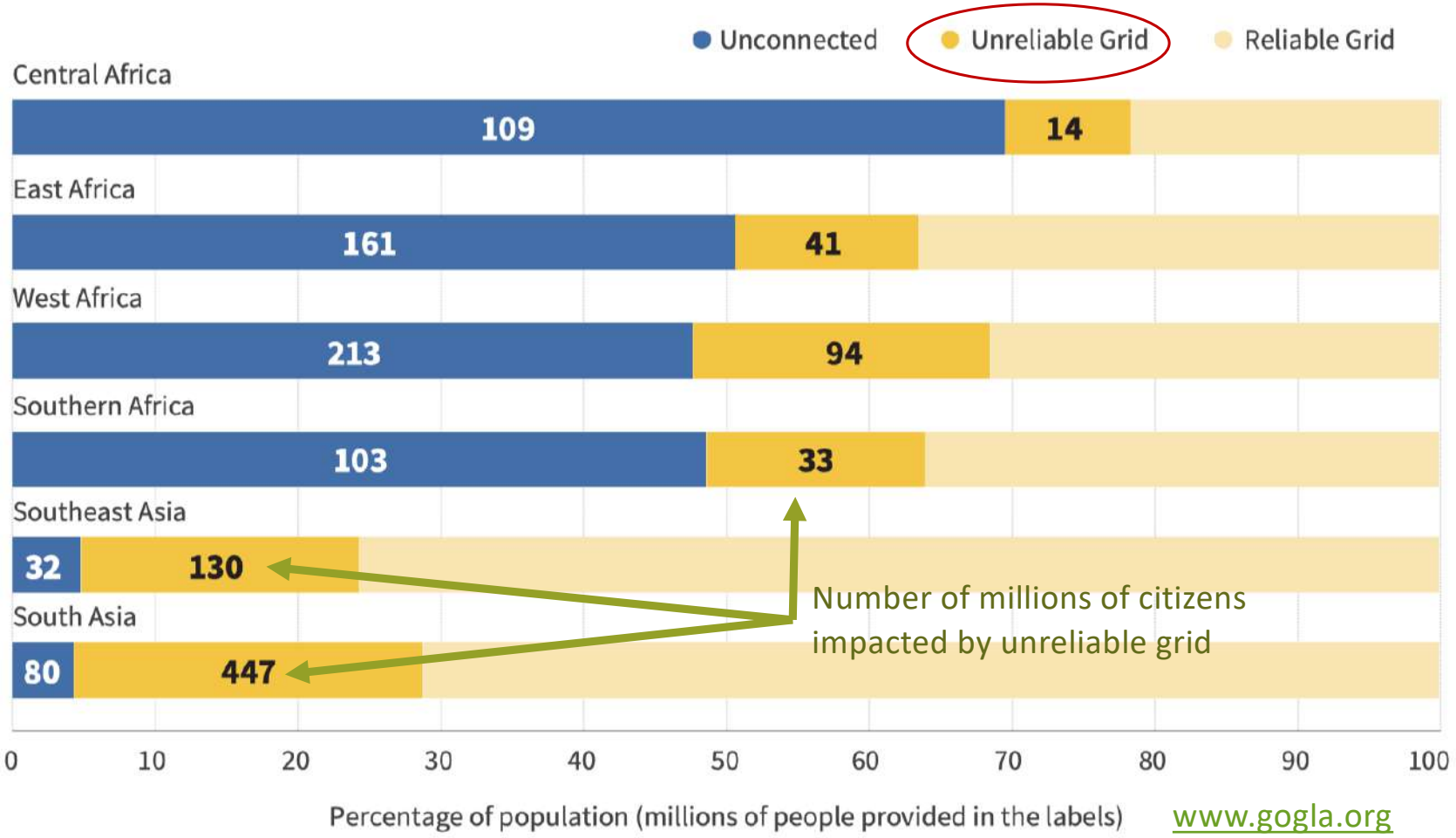
Unreliable grid quantified by GOGLA (775 million)

(= population of Europe; half India or China; twice USA)



www.gogla.org

GOGLA off-Grid Solar Market Trends Report 2022: State of the Sector

Unreliable grid quantified by GOGLA (775 million)

(= population of Europe; half India or China; twice USA)

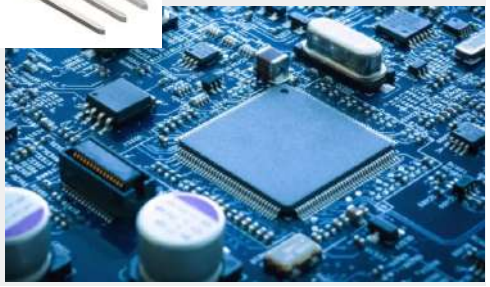
Combining these and other sources suggests that **One Billion people** suffer unreliable grid worldwide - undermining their social, economic and health-related wellbeing

Why so serious? *Power Quality and reliability impact components*

Power quality impacts many components in different and serious ways:

Significantly reduced motor torque; increased burnout; over-heating; higher inrush current; premature wear of bearings

Computer chips, MOSFETs, VSDs: destroyed by spikes; data loss from voltage interruptions of 0.2 – 2 sec; tripped by voltage sags



Lamps: CFLs don't light; incandescent low light or burn out faster

Images: ABB, RS, Philips

Why so serious? *PQ and reliability set the trajectory for the social and economic development from energy access*

Instead of powering prosperity, poor reliability and low power quality mean:

High spending on *backup diesel generators*, plus the pollution they cause

Appliances do not work, fail more quickly or need protection equipment

Economy, healthcare, wellbeing and resilience of communities are *all undermined*

Why so serious? *Often a hidden problem*

- Very low awareness of the existence of poor power quality and the problems it causes
- Insufficient policy action on poor reliability
- No formal characterising of severity and impact on communities, nor how widespread it is
- Reluctance to acknowledge because seen as failing of grid investment to date (and utilities)

Therefore: Lack of motivation (priority) to address it

If you can't measure it, you can't manage it

Or in this case:

If you can’t describe and understand it clearly, you won’t get the investment to fix it

What can be done about it? (examples)

Demand side

- Understand and quantify the PQ problem (affordable power quality sensors that are IEC-compliant)
- Affordable voltage stabilisers and local supply protection
- Appropriately resilient and labelled appliances (teach designers and buyers about PQ immunity)
- Standards and regulations that address immunity

Supply side

- Map out and quantify socio-economic consequences, to unlock investment
- Investment to address power quality, informed by monitoring
- Consumer-focused electricity regulation
- Transparency of PQ data for regulators and consumers (e.g., A to F graded)
- End-user rebates when PQ fails (e.g., Peru, Panama, eastern Europe)

What role for the EEDAL community in this?

- Multinational manufacturers export appliances to Global South markets
- EEDAL experts help transpose Global North test methods and policies to Global South economies

… which take no account of unreliable grid problems.

And so we perpetuate the problem!

We could help with solutions:

- Appliances designed to cope with unreliable grid and survive disturbances
- Regulatory focus on EMC emissions from equipment
- Test methods to verify all of this
- Policies to ensure appropriate appliances are available

But also: loss of power quality (and even reliability) is increasingly a Global North problem too!

Example: New IEC standard for refrigerators designed for unreliable grid (and off grid)

IEC 63437 *Off grid and unreliable grid refrigerating appliances for domestic and light commercial use – Characteristics and test methods - Performance requirements and energy consumption*

Working Group Convenor, TC59M WG6: Patrick Beks (co-author of this paper)

- This pioneering standard is now at Committee Draft stage (open for comment to end October)
- Expected publication Jan 2026

- Tests to grade appliance performance under intermittent and distorted supply Voltage categories
- Grades appliance for safe shutdown under 'withstand' Voltage categories
- Also tests for performance with simulated solar photovoltaic supply

Should inspire rollout of similar tests to other appliances

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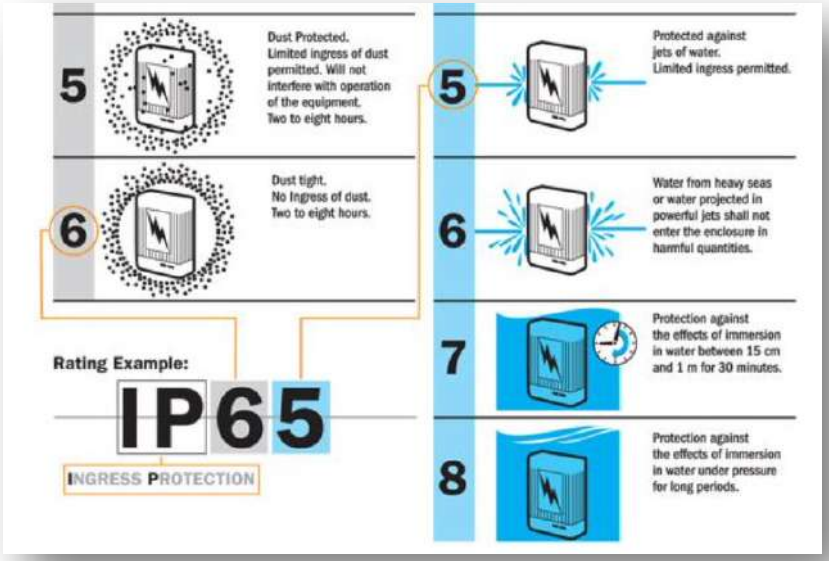


Unreliable Grid Protection Code (UGP-Code)

Consists of three digits: UGP-Class-XYZ:

- X represents the AC Voltage intermittent supply class
- Y represents the AC Voltage distorted supply class
- Z represents the AC Voltage withstand supply class

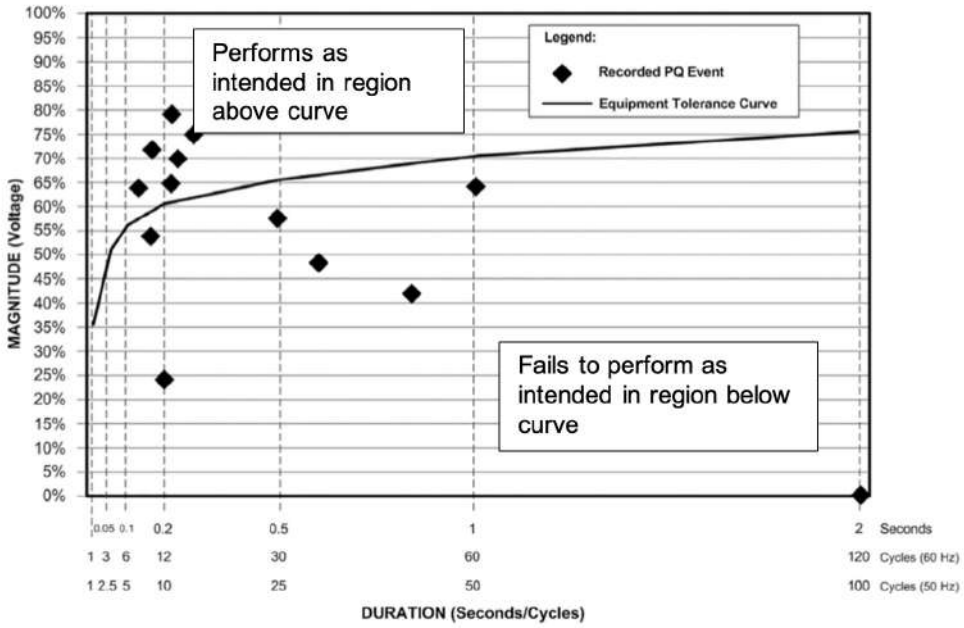
The UGP Code of a refrigerating appliance must be matched with the properties of a local grid in a specific region, ensuring proper operation of the appliance.

Should inspire rollout of similar tests to other appliances

Example: appliance design for immunity

- Vulnerabilities of most components are well understood, e.g., ITIC curves; voltage tolerance envelopes
- Engineers use this to evaluate impact of PQ disturbance events on appliances
- Appropriate immunity to power quality events can be designed into the appliance

Manufacturers have to protect their reputation and reduce warranty claims.



Voltage sag tolerance curve, with power quality (PQ) event data overlaid

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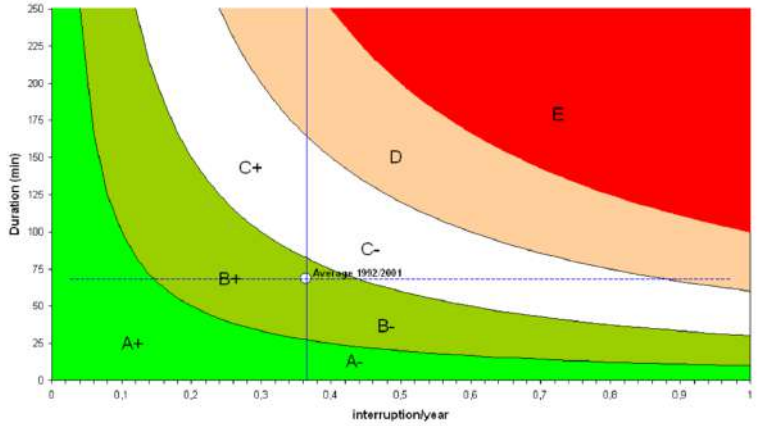
Advertisement from Lahore, Pakistan: refrigerators operable on supply between 120V and 280V; and remains cold for five days on power failure

Example: power quality data that policy makers, regulators, and appliance sector can use

- Graded supply categories (inspired by EU energy labeling)
- Requires analysis of monitored PQ data against benchmarks
- System already in use by Dutch utility – could be rolled out more widely



Images: Prof. Sjef Cobben, TU/e Eindhoven

Conclusions

- Poor power quality damages or destroys appliances
- Poor power quality and unreliable grid hold back well-being, socio-economic development and healthcare of communities
- This affects around one billion people, many of whom are those most vulnerable to climate and heat impacts
- Awareness of power quality conditions and impacts is low, especially amongst policy makers and development investors
- The challenges are so endemic that multiple actors must address PQ and reliability problems from many directions, routes are identified here
- *Appliance design, appliance standards and policy have an important role to play in demand side solutions.*

Thank you.

Get in touch:

jeremy@taitconsulting.de

patrick.beks@re-gent.nl

power equality INITIATIVE

Tait Consulting GmbH

Rhiza Research

Meinke energy

Tait Consulting, Rhiza Research and Meinke Energy share a mission to move beyond basic definitions of energy access and deliver high quality electricity to all.