POWERING PRODUCTIVITY IN AFRICAN GRIDS · LOUGHBOROUGH · 21-22 May 2026

Understanding the Kenyan Grid

Eng. Hicks Waswa[1] · Ms. Anne Wambugu[2]

[1] Kenya Power and Lighting Company · [2] School of Computing and Engineering Sciences, Strathmore University

SECTION 1

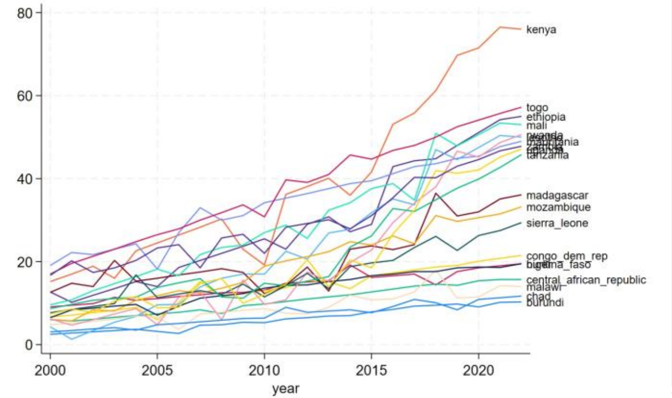
The Kenyan Grid in 2026

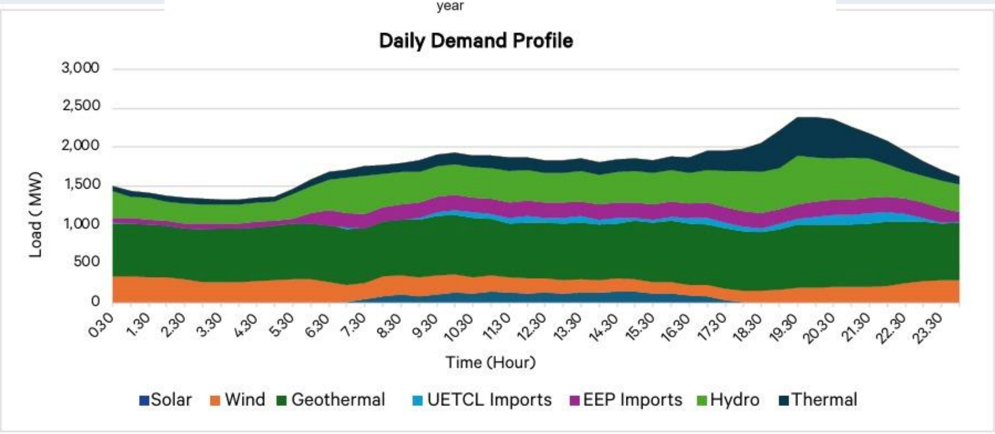
The progress: 76% electricity access. Generation capacity ahead of peak demand. Connections growing year on year.

The pressure: System losses have stayed above the regulatory threshold for years.

The blind spot: Planning relies on aggregated monthly data — we see the totals, not the patterns.

The horizon: E-cooking and e-mobility are about to add load shapes we haven't seen before.





Load Curve 2025

Loss Number vs Anatomy

22.07%

Actual Total Losses

(improved from 24.08%)

16.50%

Regulatory Threshold

EPRA target

5.57%

Gap Still To Close

billions in unrecovered revenue

Current Visibility

- The aggregate loss figure (22.07%)
- Data from substations and feeders
- Customer billing records and connection counts

Loss Anatomy

- Loss precision split into technical and commercial categories
- Loss mechanism at distribution level e.g., power factor vs harmonics vs theft vs others
- How much energy is missed by meters versus stolen outright
- Which customer load profiles drive the worst losses
- Where targeted intervention will move the number most

The Planned National Study

83,626

transformers

to be audited nationally

19,612

Phase 1

Nairobi region

April 2026

Start month

the work is underway now

The Method

Power Quality Analyzer

Deployed at the metering panels to capture: PF, THD, TDD, Crest Factor, K-Factor, harmonics to the 50th order.

Smart Meter Audit

Compared against the PQA to identify variance per phase, if any

Geospatial & Satellite

VIIRS night-time light imagery used to flag suppressed demand zones, thermal anomalies, and supply instability.

Load Survey

Customer load profiles cross-checked against monthly kWh — to see beyond averages.

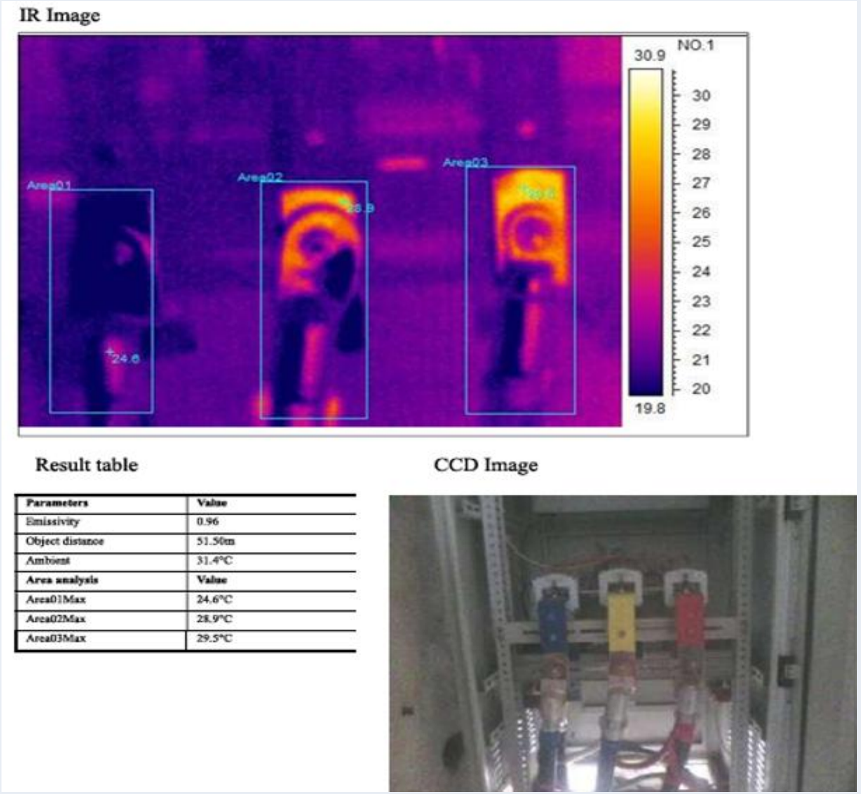
Grid Stress - Context

What people assume:

- Old infrastructure
- Load-shedding
- Poor maintenance
- Theft

What analysis shows thus far:

- Overloaded transformers from:
    - Poor power factor
    - Harmonics.
- Aging assets stressed far beyond their K-1 design rating.
- Cascading failures from interconnected faults.



Parameters	Value
Emissivity	0.96
Object distance	51.50m
Ambient	31.4°C
Area analysis	Value
Area01Max	24.6°C
Area02Max	28.9°C
Area03Max	29.5°C

Thermal imaging of supply interface

Reliability - The Customer Side

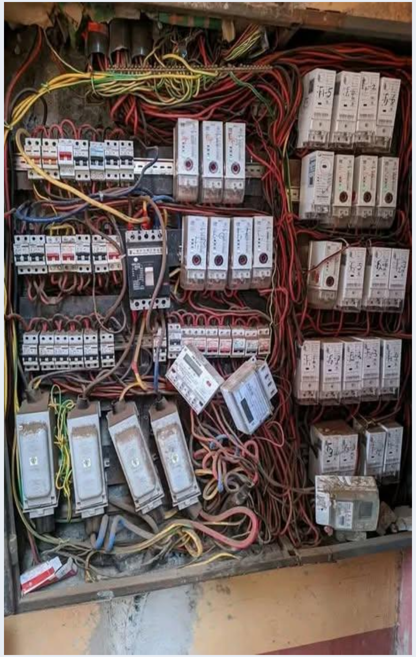
From the Customer Side

What people assume:

- Customers just pay bills and report outages.
- Load is predictable.

What analysis shows:

- Customer load quality (harmonics, poor PF) directly impacts utility assets.
- Smart meters configuration can miss energy because of customer-side distortion.
- Informal wiring amplifies losses invisibly.

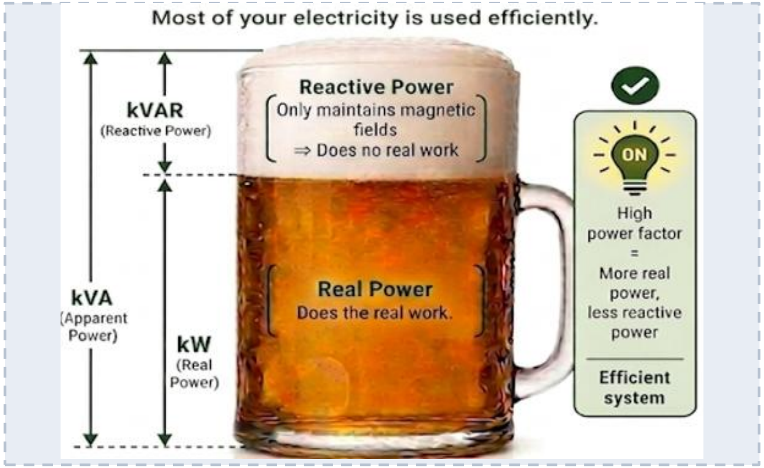


Informal wiring case

Power Factor - The Beer Analogy

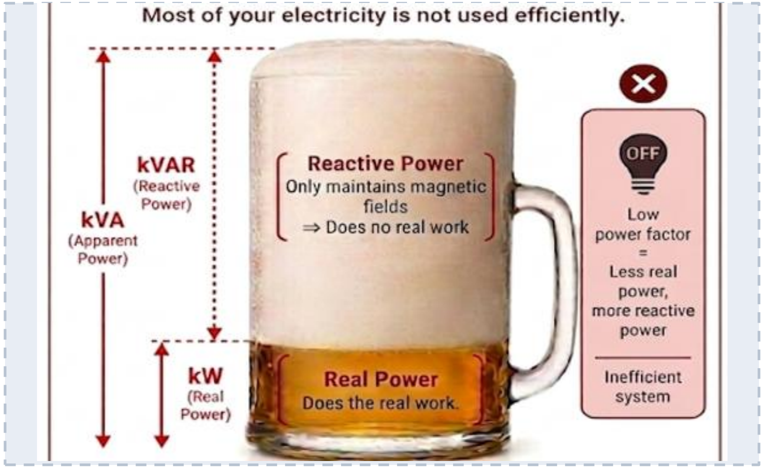
POWER FACTOR = REAL POWER (kW) / APPARENT POWER (kVA)

GOOD POWER FACTOR → 0.9



High power factor → most of your electricity quenches your thirst and does useful work.

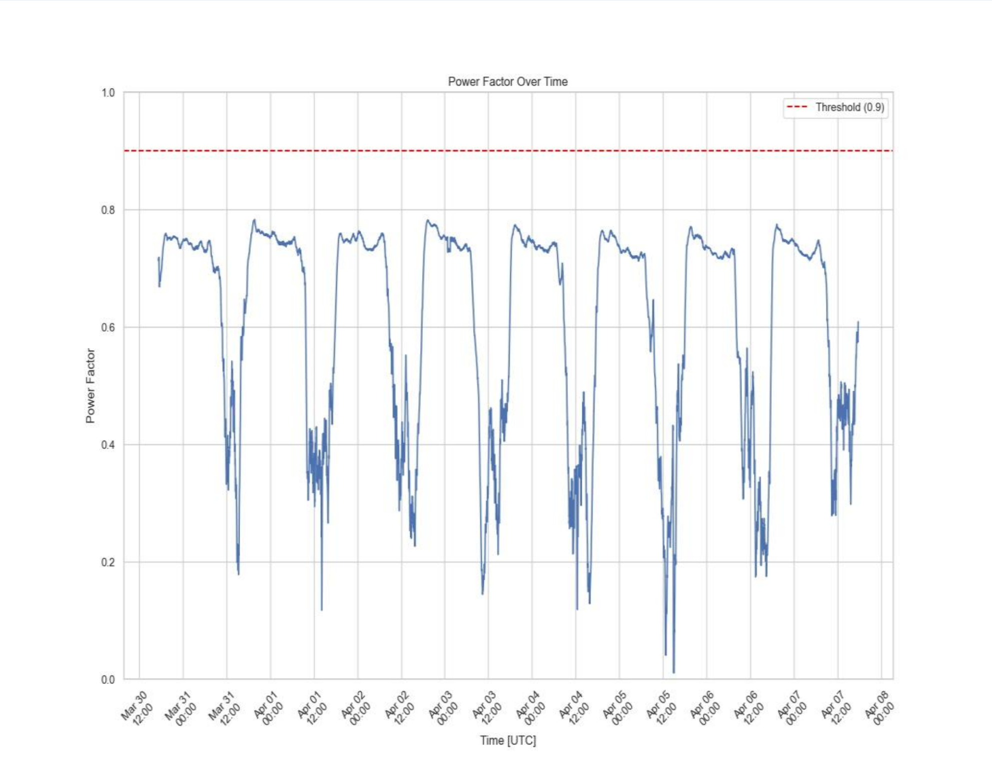
LOW POWER FACTOR → 0



Low power factor → most of your electricity is foam that does no useful work.

Power Factor - Case Study

- Baseline PF ≈ 0.70
    - Regulatory minimum: 0.90
- Mid-day PF collapse to near zero.
- Transformer kVA loading 2× the metered kW billing.
- Energy Act 2019: 2% surcharge per 1% the PF is below 0.90
- Current research question
    - What is the root cause?

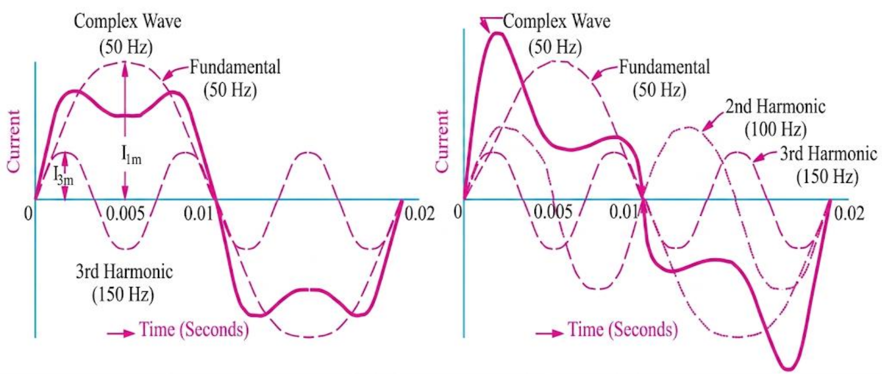


Power factor time-series

Harmonics - Context

- Non-linear loads inject current at multiples of the 50 Hz fundamental.
- Replacing one incandescent bulb with five LEDs.
    - Each LED chops the power supply electronically, dozens of times per second.
- One LED? Invisible.
    - An entire building? Manageable.
- A million homes and businesses all doing the same — with LEDs, phone chargers, computers, inverters — stacks into serious harmonic distortion.
- The electrical noise overheats transformers, blows fuses, and causes smart meters to under-count actual consumption.

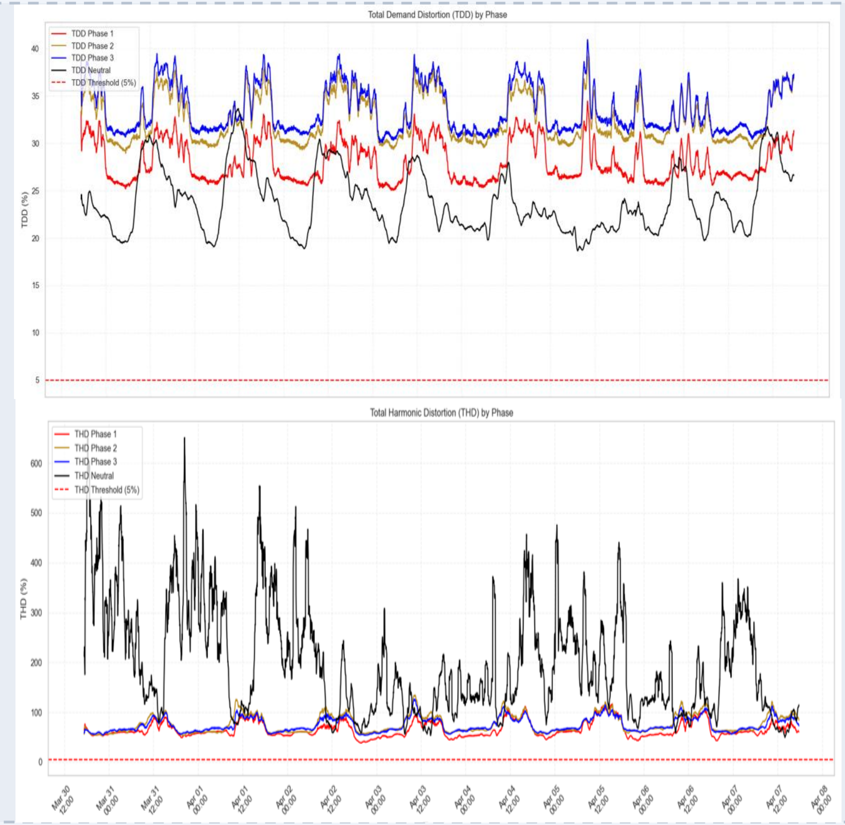
The LED Transition



Complex waveform

Harmonics – The Case Study

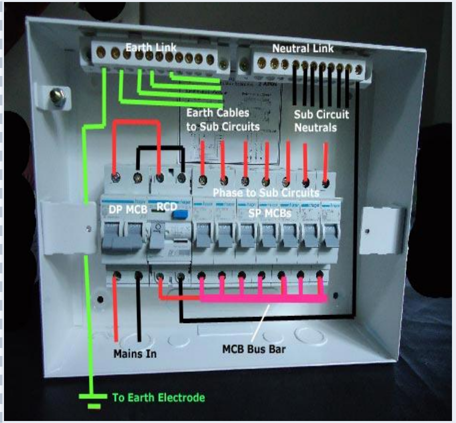
- Per-phase THD > 100%
    - IEEE 519 / KNDGC limit: 8%, 12%, 15%
- Neutral THD peaks at 600%
    - Triplen harmonics (3rd, 9th, 15th) add up arithmetically
- TDD across all phases: 25–40%
    - IEEE 519 limit: 5%
- Crest Factor ≈ 2
    - Ideal: 1.414
- CT saturation under-counts 20 A per phase of unmetered current.
    - This means **USD 20,000/year** in unbilled energy for a single customer

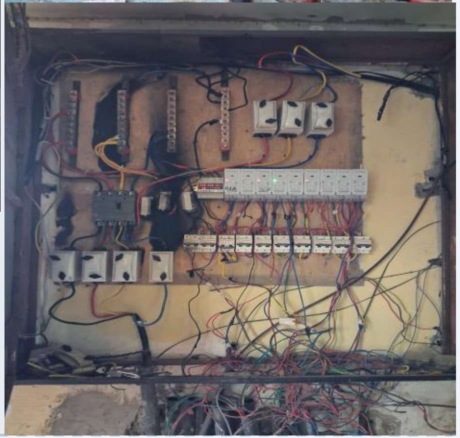


Harmonic distortion charts: per-phase + neutral waveform stack

Informal Wiring

- The informal technician workmanship is poor
    - Uses thin cable and skips the earth wire etc.
- Multiplied across millions of homes and businesses, these installations become invisible damage to the grid.
- Undersized cables heat up and the utility's hardware behind the meter bears the cost.
- **This is not a fault problem.** It is a frequent practice.
- **This is not a theft problem.** It is a quality problem the utility cannot disaggregate using conventional practices.





Wiring examples

Informal Settlements

Status quo assumption:

- People in informal settlements connect illegally because they want to steal electricity and avoid paying.

Evidence thus far:

- No land title → no formal connection eligibility.
- High upfront connection fees exclude low-income households.
- Many residents pay landlords or resellers more per unit than a formal tariff would cost — for worse, less reliable service.
- Daisy-chained meters hide load from the utility entirely.
- The utility cannot apply targeted tariffs or demand management to what it cannot see.

Informal settlement connection

Commercial Losses — What Never Gets Billed

Category 1: Active Theft:

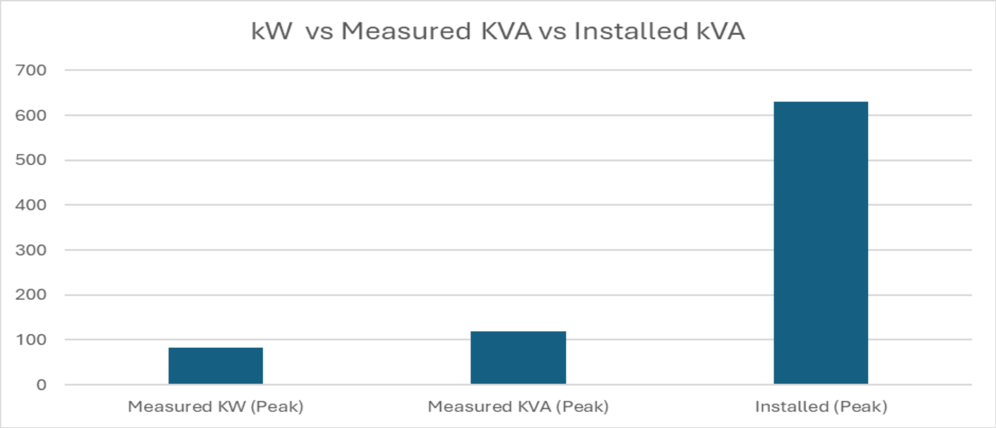
- CT bypass / short-circuit on secondary winding
- Meter tampering, clock manipulation
- Unauthorised tapping upstream of meter

Category 2: Passive Loss:

- CT saturation from high crest factor (> 2.2) causing under-reporting
- ADC under-sampling: meters sampling at 2 kHz miss harmonics above 1 kHz (Nyquist limit)
- Harmonic-induced measurement error persists even with certified meters

Case study finding:

- 20 A unmetered per phase → 310 kWh/day.
- CT saturation from high crest factor (≈ 2.2) causing under-recording.
- ADC under-sampling; meter sampling at 5 kHz misses harmonics above 1 kHz (Nyquist limit).
- Unauthorised tappings eliminate billing entirely.



SECTION 3

What Losses Do to the Network

Transformer Derating

- K-Factor measured at K-25 to K-50 at the case study site.
- Design rating: K-1.
- A 630 kVA transformer operating at K-30 effectively delivers ~150 kVA.
- **We pay for capacity we cannot use.**

Insulation Degradation and Fire Risk

- High-frequency harmonics generate dielectric stress on transformer insulation.
- Triplen harmonics heat capacitor electrolytes, causing bulging or rupture.
- **Asset life shortens by years.**

Capacitor and Contactor Failure

- Power factor correction capacitors — installed to fix the problem — are themselves destroyed by harmonics.
- Distorted voltage zero-crossings pit contactors and cause premature burn-out.
- **Destroyed capital investment in pf banks.**

CT Saturation - Revenue Gap

- Peak current ≈ 2× RMS (crest factor ≈ 2) saturates the metering CTs.
- The meter sees a clipped, under-magnitude signal and records less energy than was consumed.
- **The loss is invisible in audits.**

The Financial Cost - The Case Study

USD 20k

Annual billing loss

from CT saturation alone

USD 46k

Annual PF penalty cost

Energy Act 2019 surcharge

USD 66k

Total lost annual revenue

at one site, in one year

The Shared Cost Chain — Why Everyone Has an Incentive to Fix This

Utility (KPLC): Unrecovered revenue, stranded transformer capacity, asset replacement costs — total losses at 22.07%, vs 16.50% target.

Consumers: Higher tariffs to cover socialised losses, equipment damage from poor power quality.

Regulator (EPRA): Pressure to approve tariff increases that could be avoided if losses were contained.

Economy: Unreliable supply impedes productivity, inflates costs of e-cooking and e-mobility adoption, deters investment.

A Joint Agenda

Reduced System Losses

22% → 16.5% target

Lower Utility Costs

Less recovery, longer asset life

Fairer EPRA Tariffs

Cost-reflective, not loss-padded

Consumer Productivity

Stable supply lifts incomes

Better Load Behaviour

PF, harmonics, formal connections

The loop reinforces itself when every stakeholder plays their part.

THANK YOU

Feel free to talk to us.

Eng. Hicks Waswa
Ms. Anne Wambugu · annewacera.com