Microgrids in Southern Africa

EnergyVille 2023 Symposium on Microgrids – Genk, Belgium

CT Gaunt

University of Cape Town

Lucingweni, E Cape, S. Africa

Presidential Project managed by the National Electricity Regulator.

- 560 x 100 Wpk PV panels
- 6 x 6 kW wind generators
- 2.2 MWh battery bank
- 100 kW bi-directional inverter 220 Vdc/400 Vac

AC distribution to 220 dwellings, each restricted to 2 A at 230 V.

Lucingweni failure

Over-promise, under-delivery

Inadequate capacity

No operator appointed

Lack of maintenance

Frequent breakdowns

Customer dissatisfaction

Electricity theft

Vandalism

Equipment theft

End of microgrid project

Eskom grid supply with Free Basic Electricity tariff

Skeletal evidence of a failed project

Robben Island, Cape Town

Previously supplied by a diesel generator.

2017: 666 kW PV installation and 837 kWh LI-ion batteries added – connected to existing 11kV grid.

Diesel for back-up and about half the energy needs.

Project cost R25 million (~ €1.7 m)

Agricultural projects

Processing, pumping, facilities – isolated or grid-connected

Seeds of Hope, Zambia

- 500 kVA ZESCO supply
- 120 kWpk PV
- 300 kWh Li + 150 kWh Pb batteries
- 6 x 72 kW hybrid inverters
- 60 kW grid tie inverter

Orphanage

School

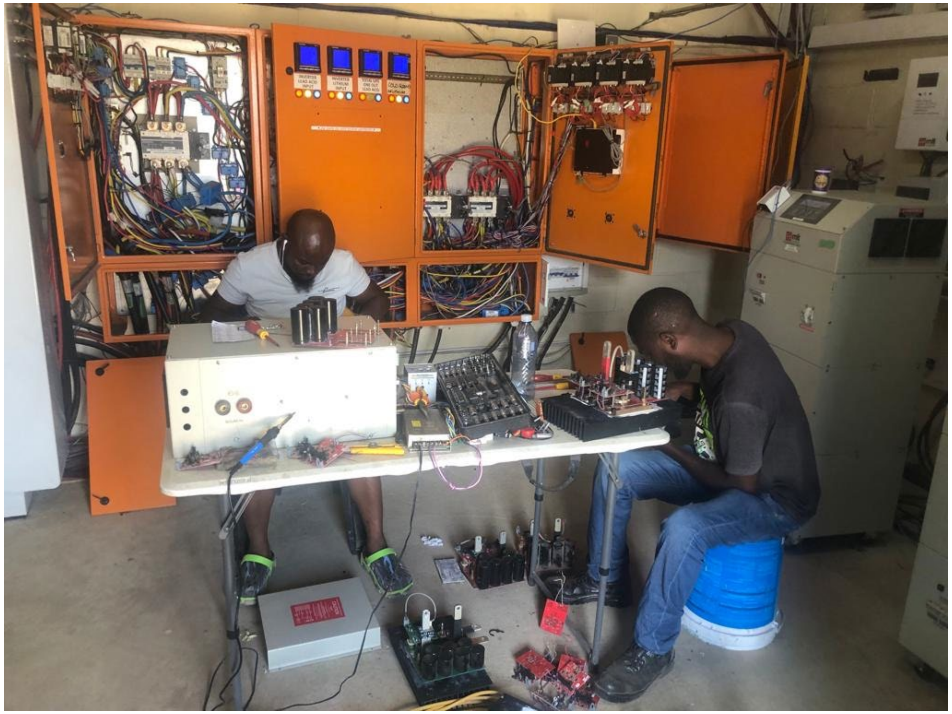
Cafeteria

Farm

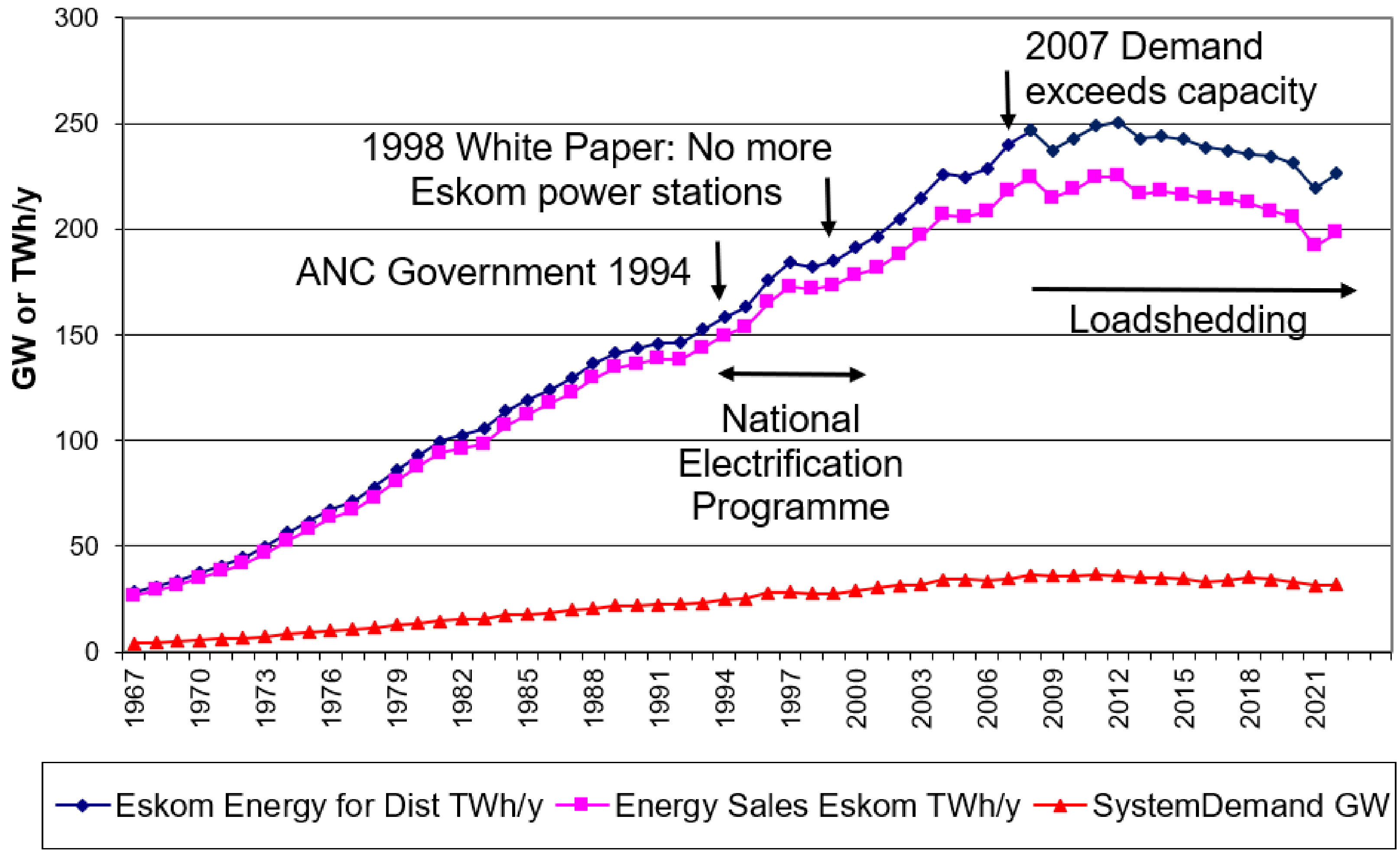
Run and maintained by local staff.

Support and monitoring from Cape Town.

Training and installation upgrades on site.



Eskom power decline in SA

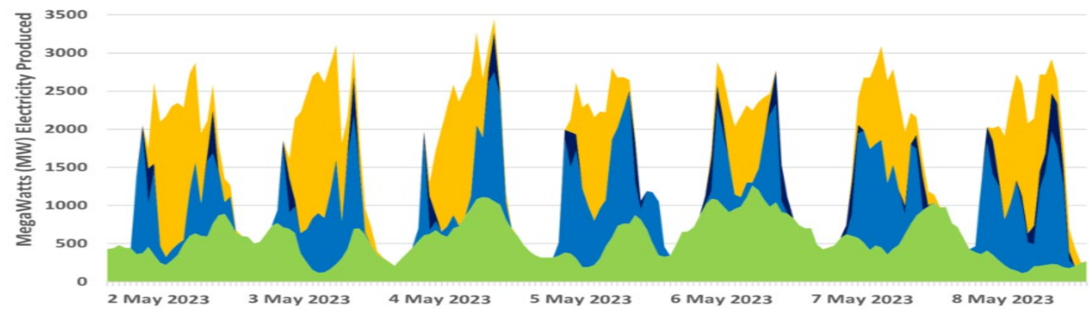


System demand May 2023

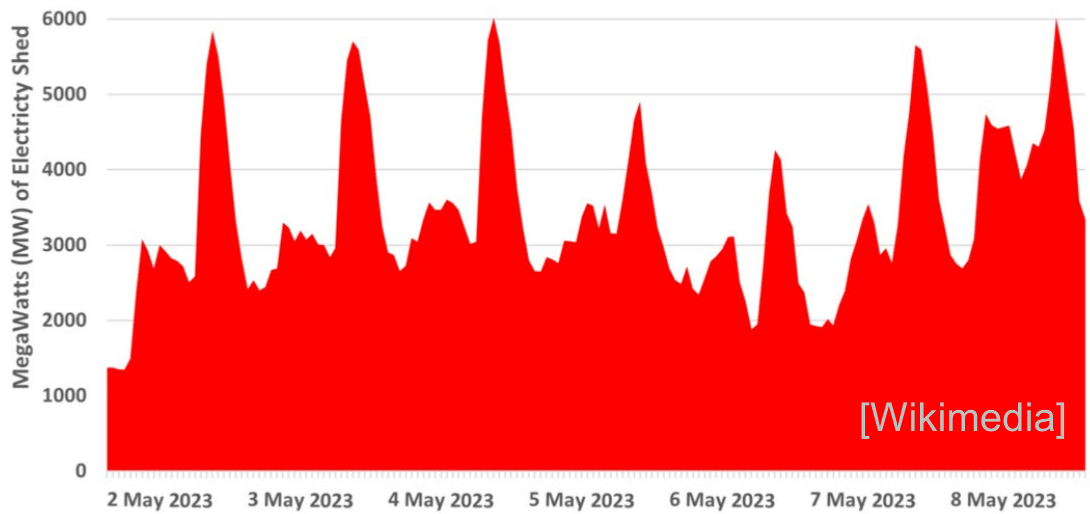
Dispatchable generation for 1st week of May: **26.3-27.8 GW**.

Dispatchable hydro and pumped storage 2.6 GW.

Renewable energy sources : ~2.5 GW;
~1.5 GWpk of PV
~1 GWpk of wind.



Rotational load shedding:
6 GW at evening peak,
2 GW 24/7



Nature of the problem

Root causes:

- Department of Energy planning and delivery.
- Regulator tariffs and licencing.
- Corruption, crime and sabotage.

Results:

- Energy poverty across all sectors.
- Declining economic activity and quality of life.

Customer response

Typical of responses to unreliable power supplies in many countries in sub-Saharan Africa.

Microgrids for reliability

Focus less about financial return on energy.

Emphasis on back-up of critical loads.

Essential for work-from-home customers.

- Simple back-up
- Energy saving
- Bi-directional energy flow

Thousands of residential and commercial microgrids, and larger industrial and mining minigrids.

Leaves the poor … ?

Main issues

Energy policy and long-term outlook.

Financial and economic balance – tariffs and investment.

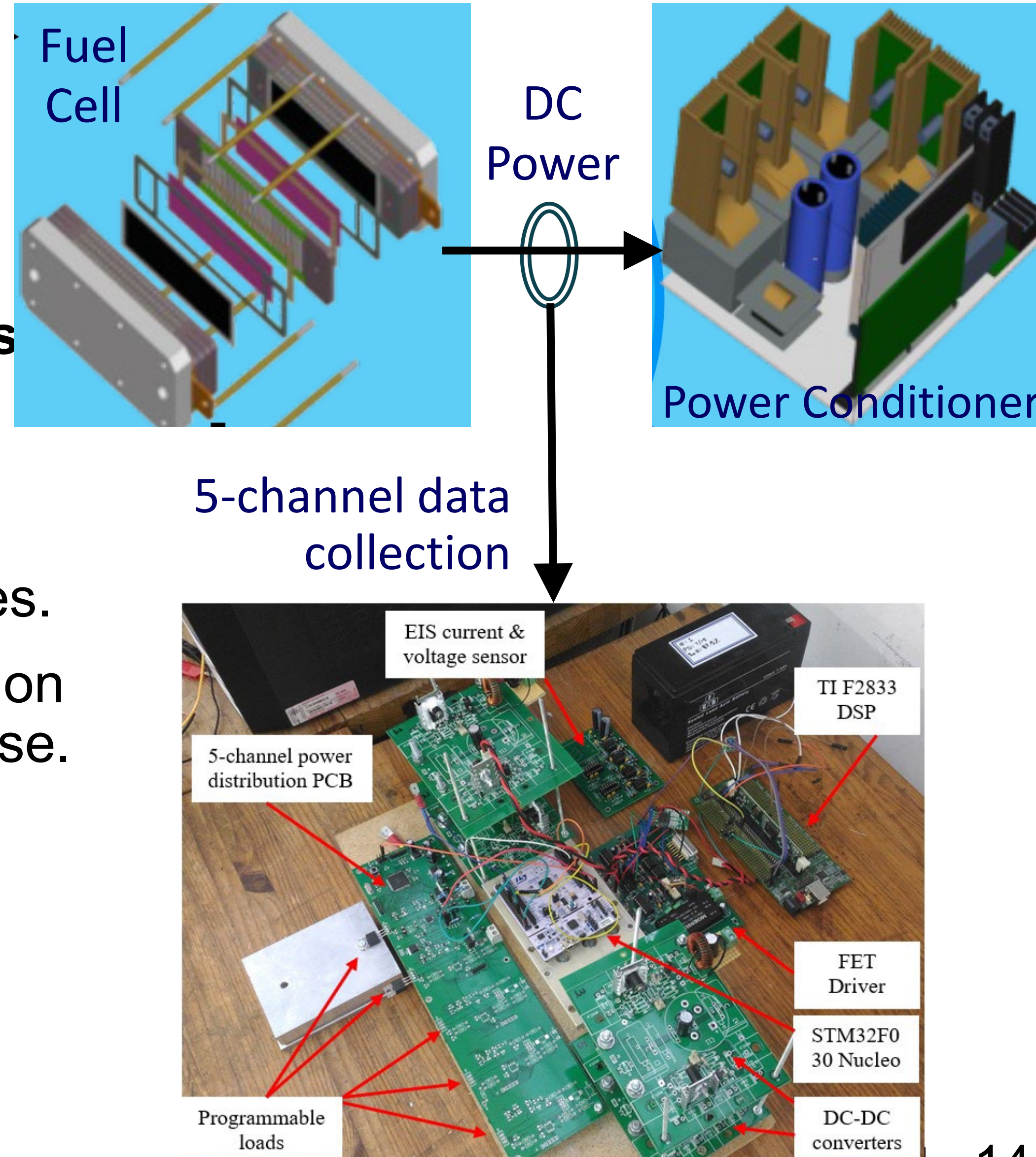
Technical performance.

Intelligent Power Conditioning

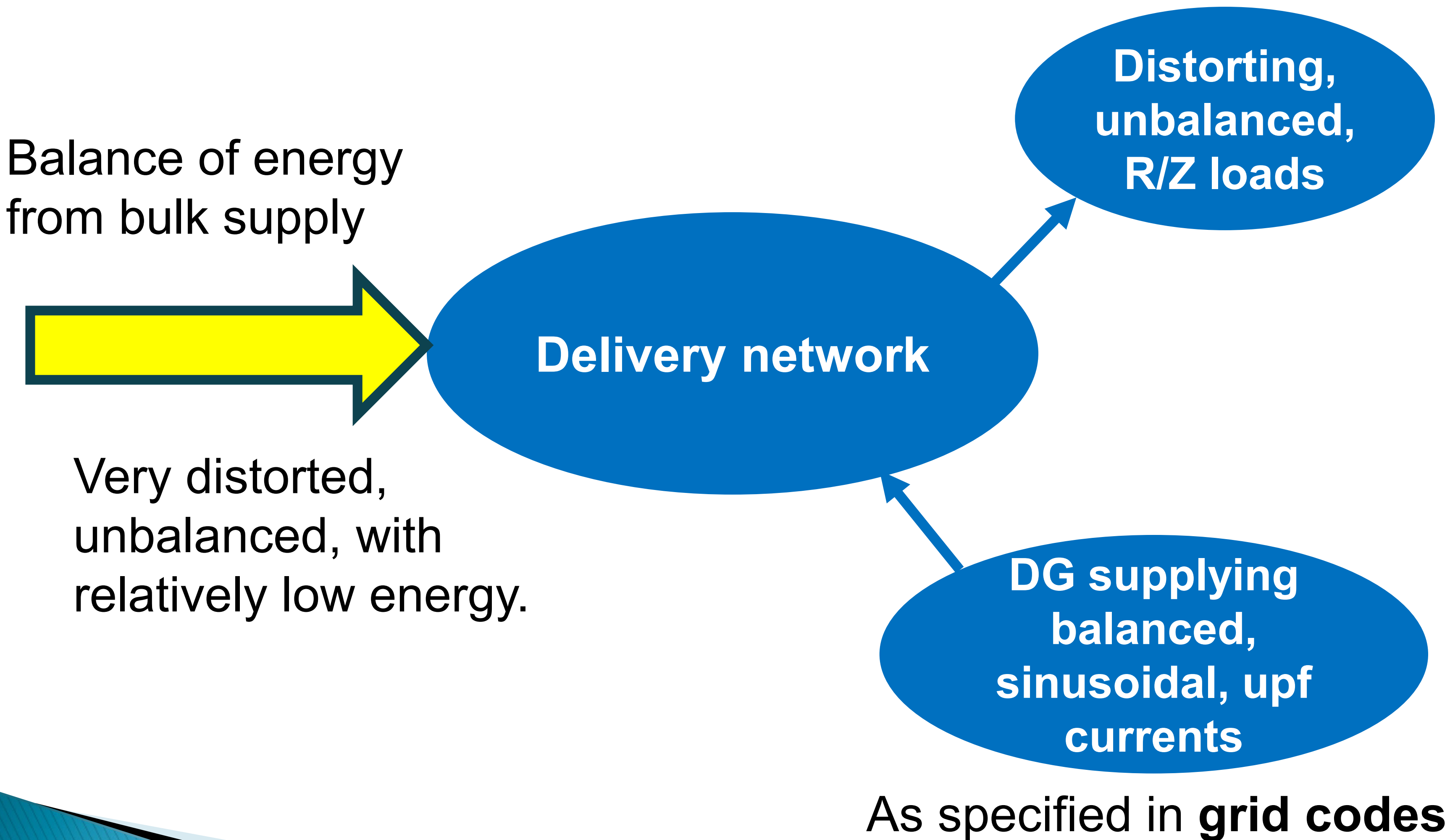
For:
- **fuel cells**
- **PV modules**
- **batteries**
- **induction machines**

Based on power electronic converter control:

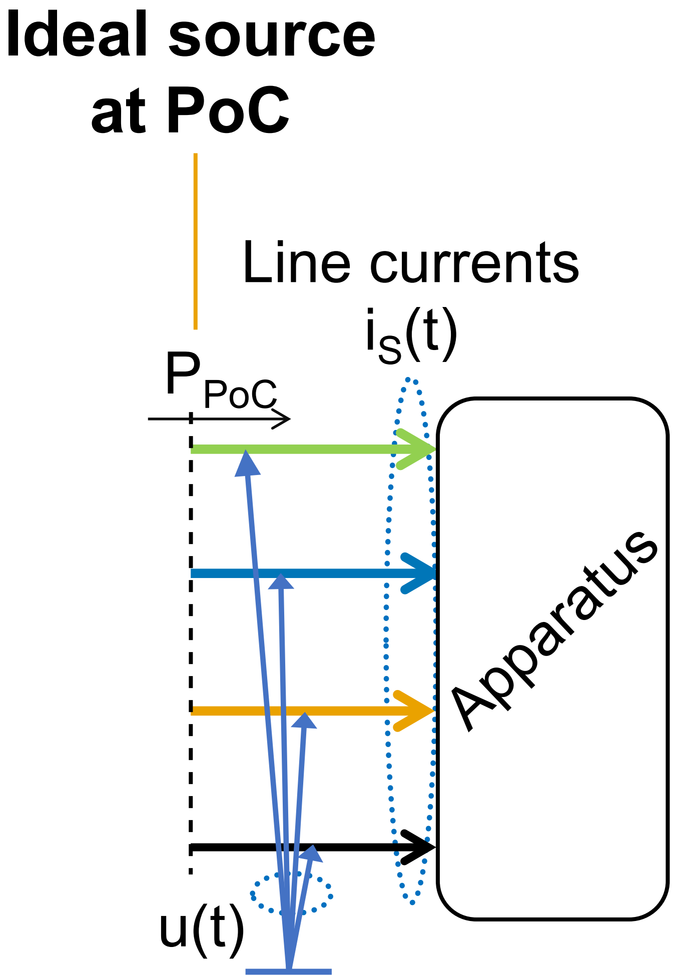
- regulate to meet objectives.
- stimulate energy conversion device – measure response.
- model for state of health assessment.
- mitigate to limit potential impact of fault.



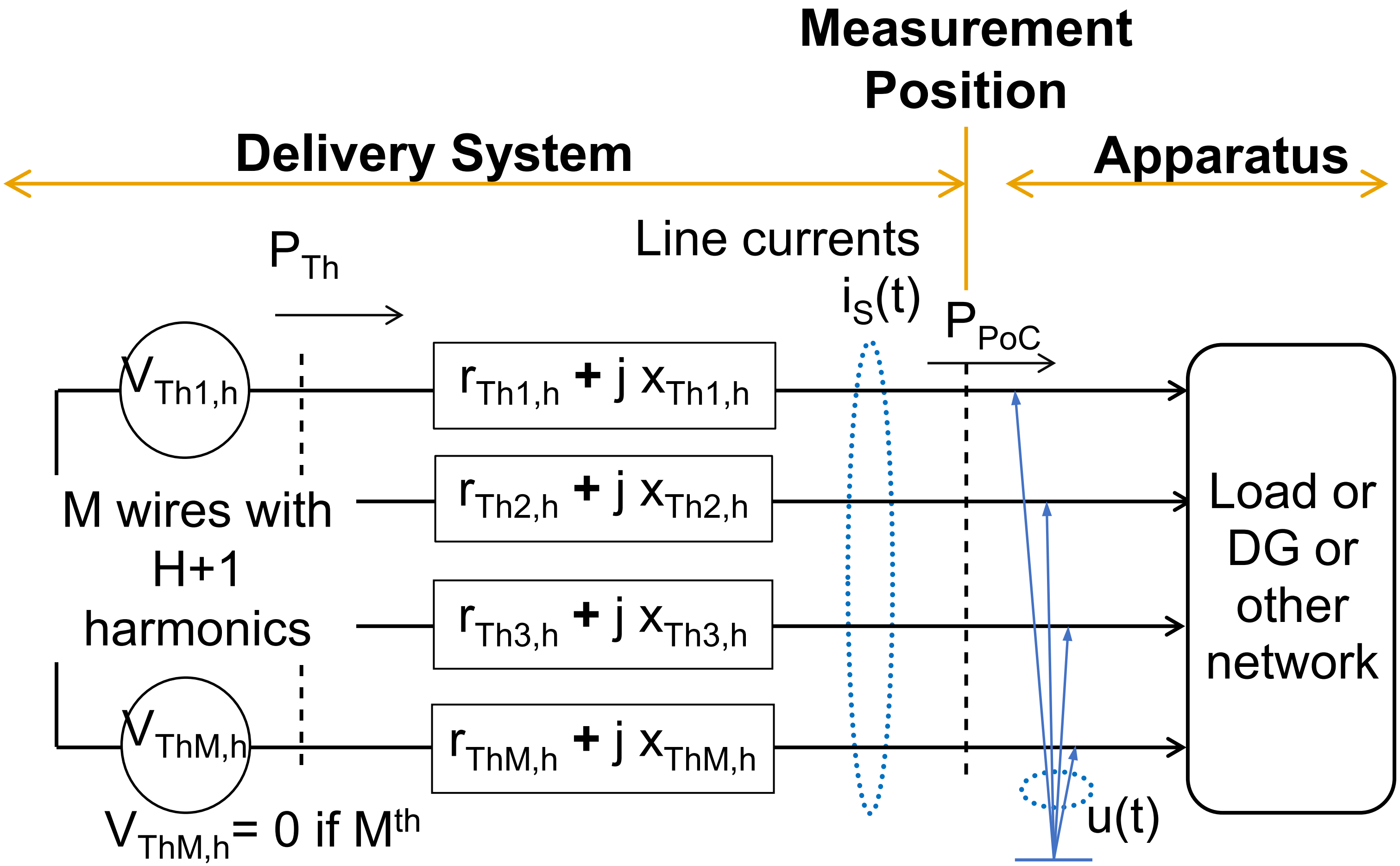
System perspective



Most power theories



Whole system measurement (concept) model



$V_{ThM,h}$= 0 if M^th wire is a neutral

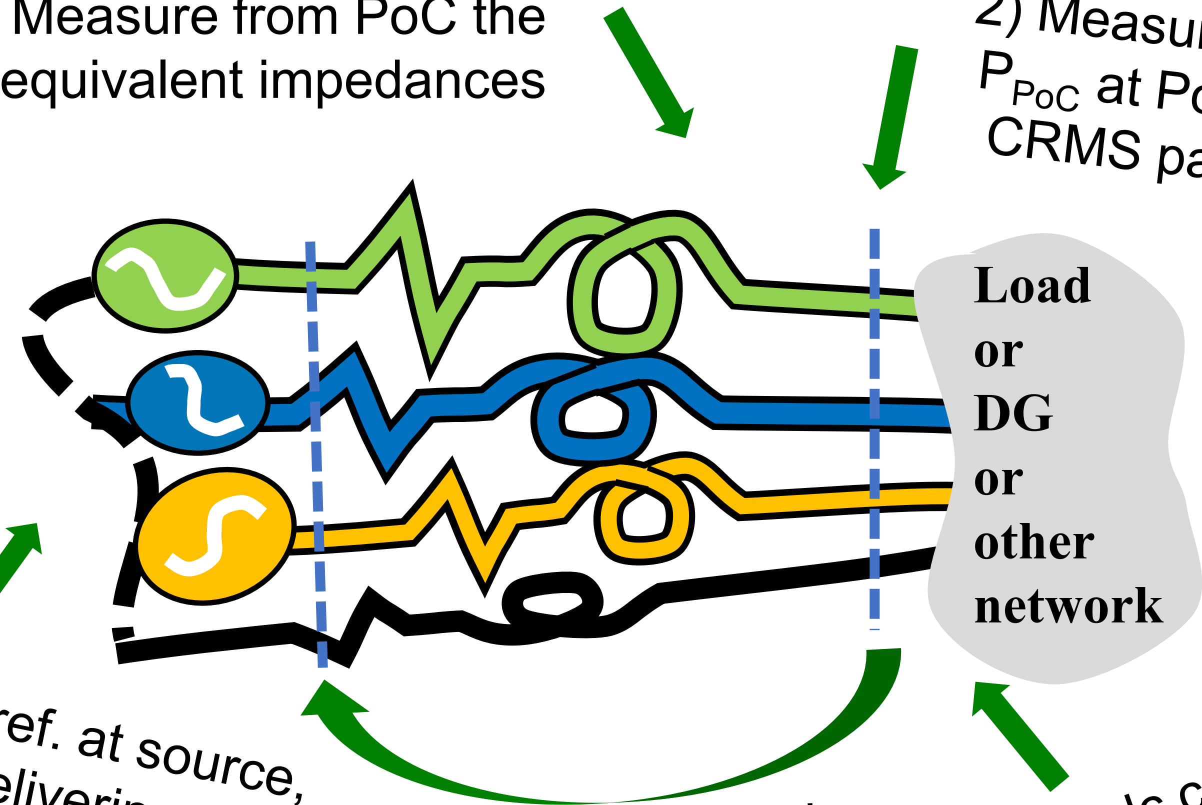
Fourier decomposition allows system to be segmented/superposed by frequency.

GPT* for practical system

*GPT= General Power Theory

1) Measure from PoC the Thévenin equivalent impedances

2) Measure i(t), v(t), P_{PoC} at PoC, derive CRMS parameters

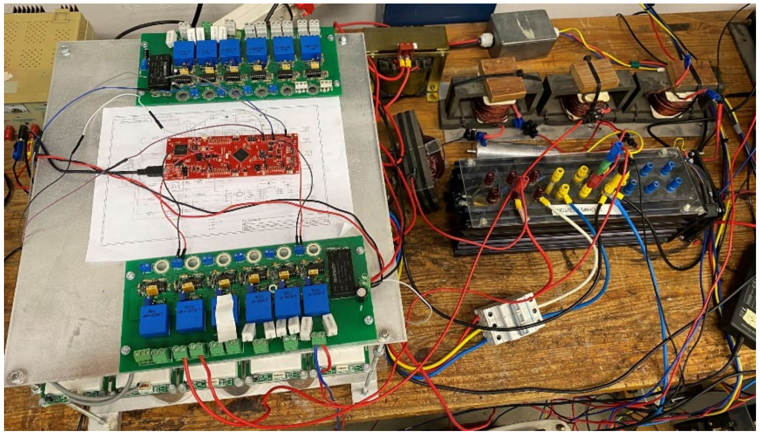


4) Find null ref. at source, currents delivering P_{PoC} with min. loss, and PF_{SYS}

3) Calc. voltage drop from source, thus source voltages

5) Calc currents for compensation

GPT-controlled inverters



Concept demo of
20 kW 3ph 4w
inverter

PHIL tests: effect
of 80 kW 3ph 3w
inverter on network

CHIL tests: 10 kW
3ph 4w inverter

Implications

Microgrids have different significance in Africa compared with developed regions.

GPT applies to all power systems:

- any number of wires,
- ac and dc,
- microgrid, minigrid, to continental.

GPT admits no reactive power – no Q! Probably, no q.

Converters can minimize losses while operating with unbalance and distortion.

Re-think reliability, power quality, volt-var control, voltage stability, grid codes, converter technology, …

… and a lot more.

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