GRID RELIABILITY: Challenges & Opportunities

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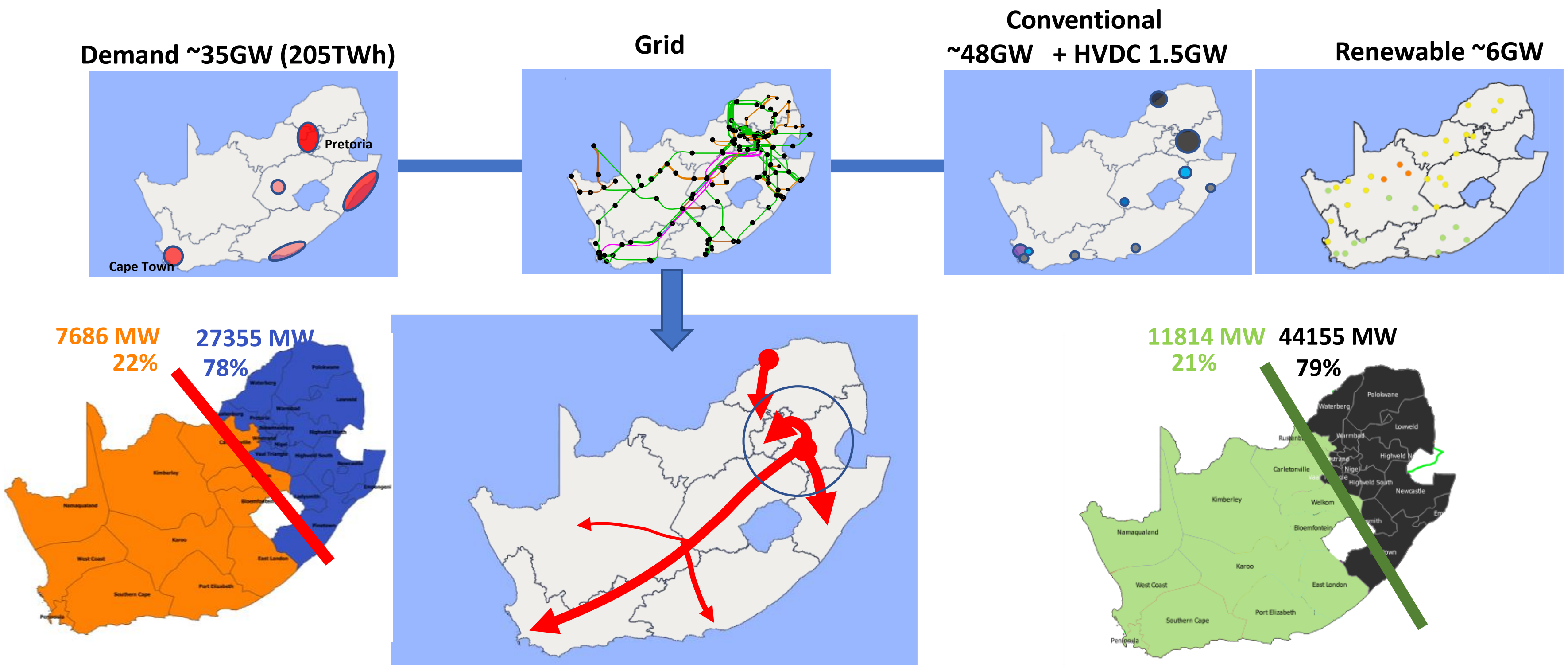
2022-02-17

Current electricity system



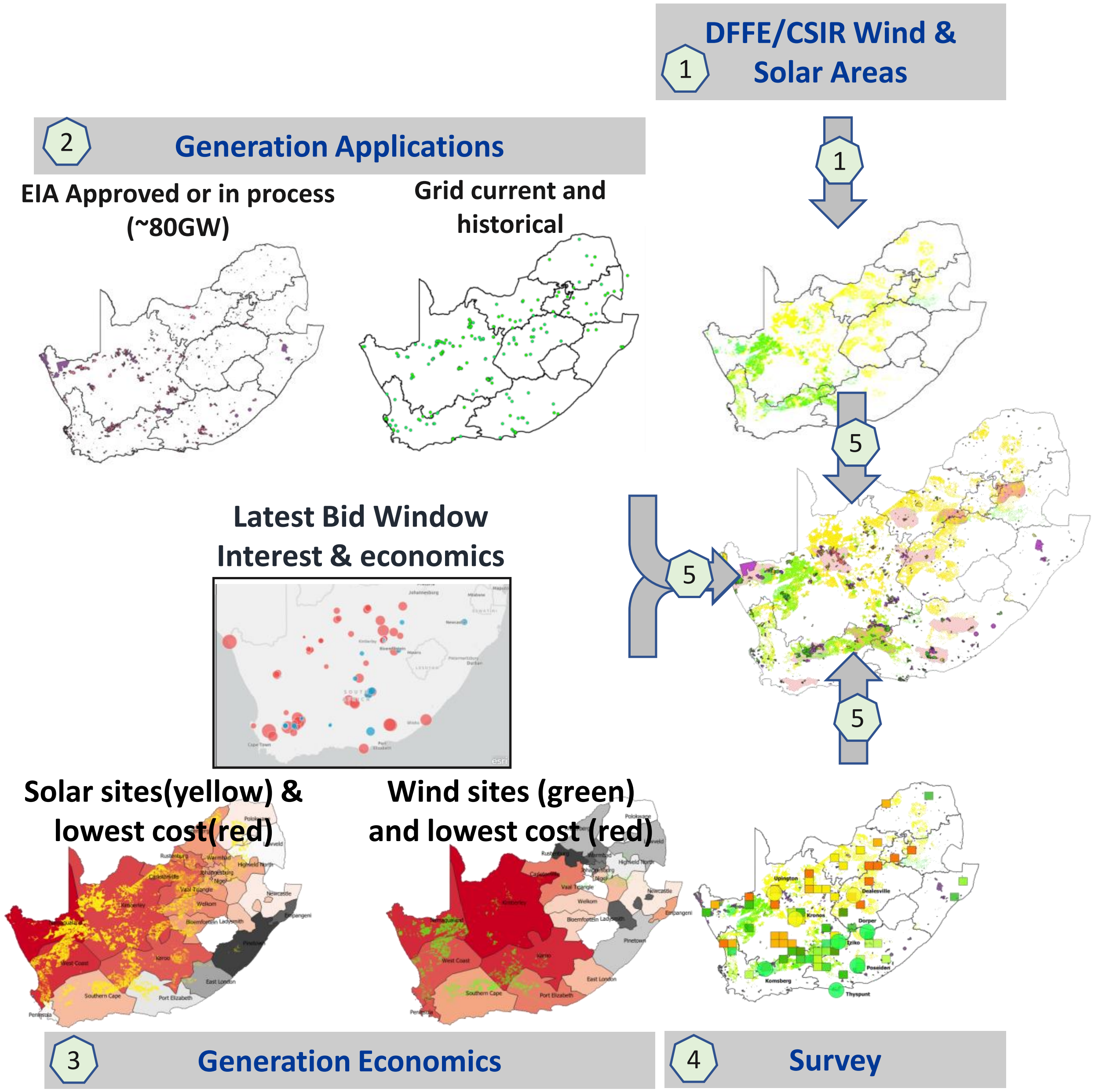
Demand

Generation

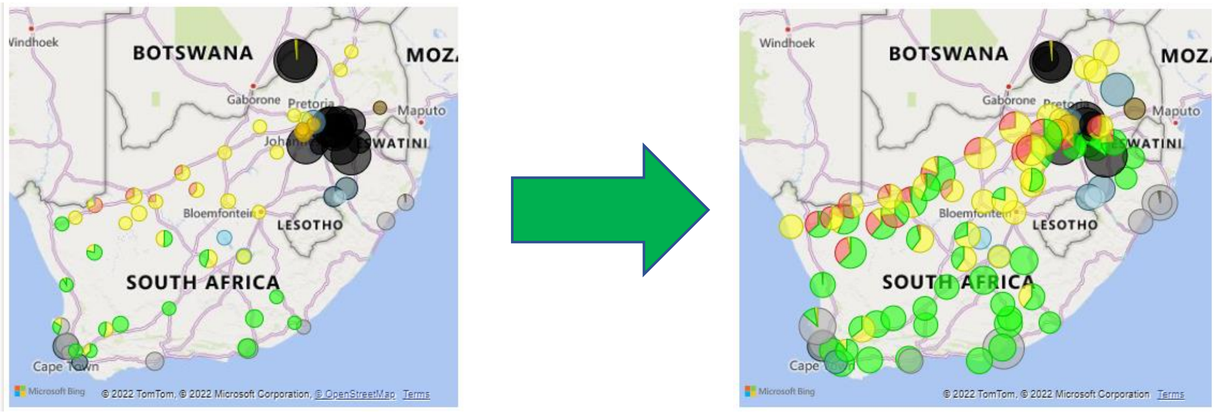
South African grid can be considered as an islanded network

Greater Cape network "Radial feed" supplying historically low load over a distance of ~1000km

Where are the high-renewable resources?

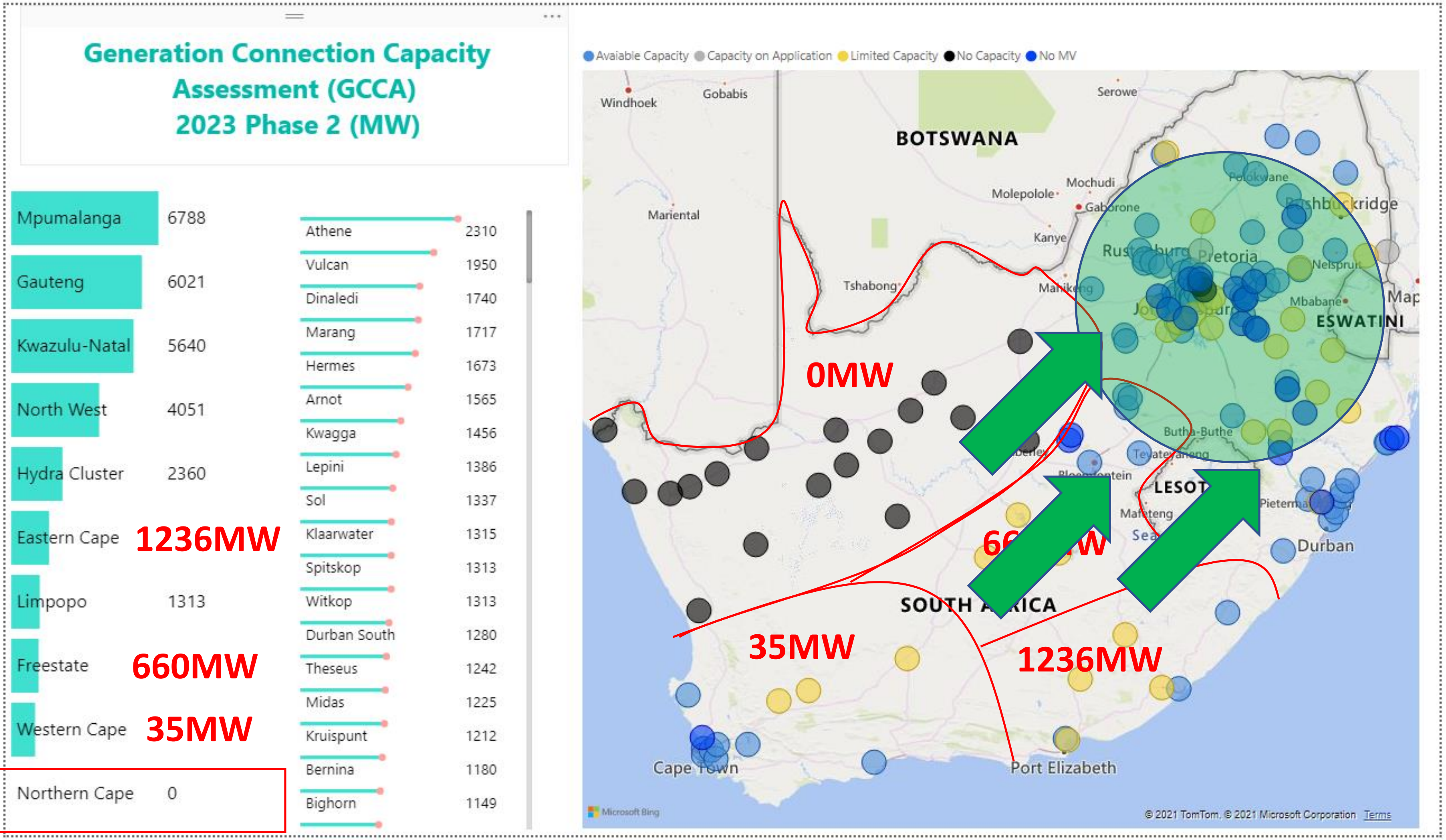


Significant change in generation locations compared to the current electricity system



This has significant impact on the need to adapt the grid access and transportation requirements

What is the current grid capacity?



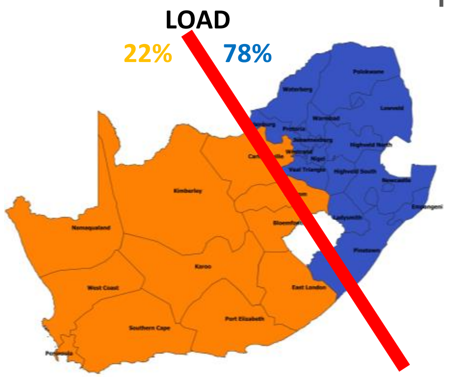
https://www.eskom.co.za/eskom-divisions/tx/gcca/

Post BW5 grid capacity is constrained in the greater Cape Area to 1931MW which is less than one bid window capacity.

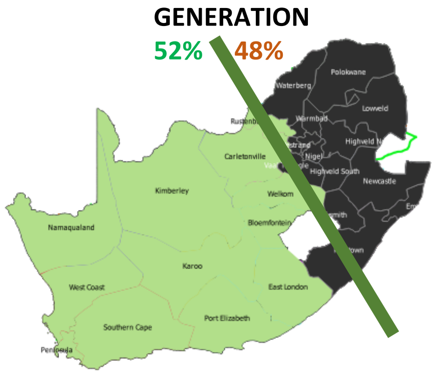
Grid expansion will require time and hence grid capacity will be greater in the northern parts of South Africa in the near term.

Grid adaption for high penetration renewable requires significant new grid.

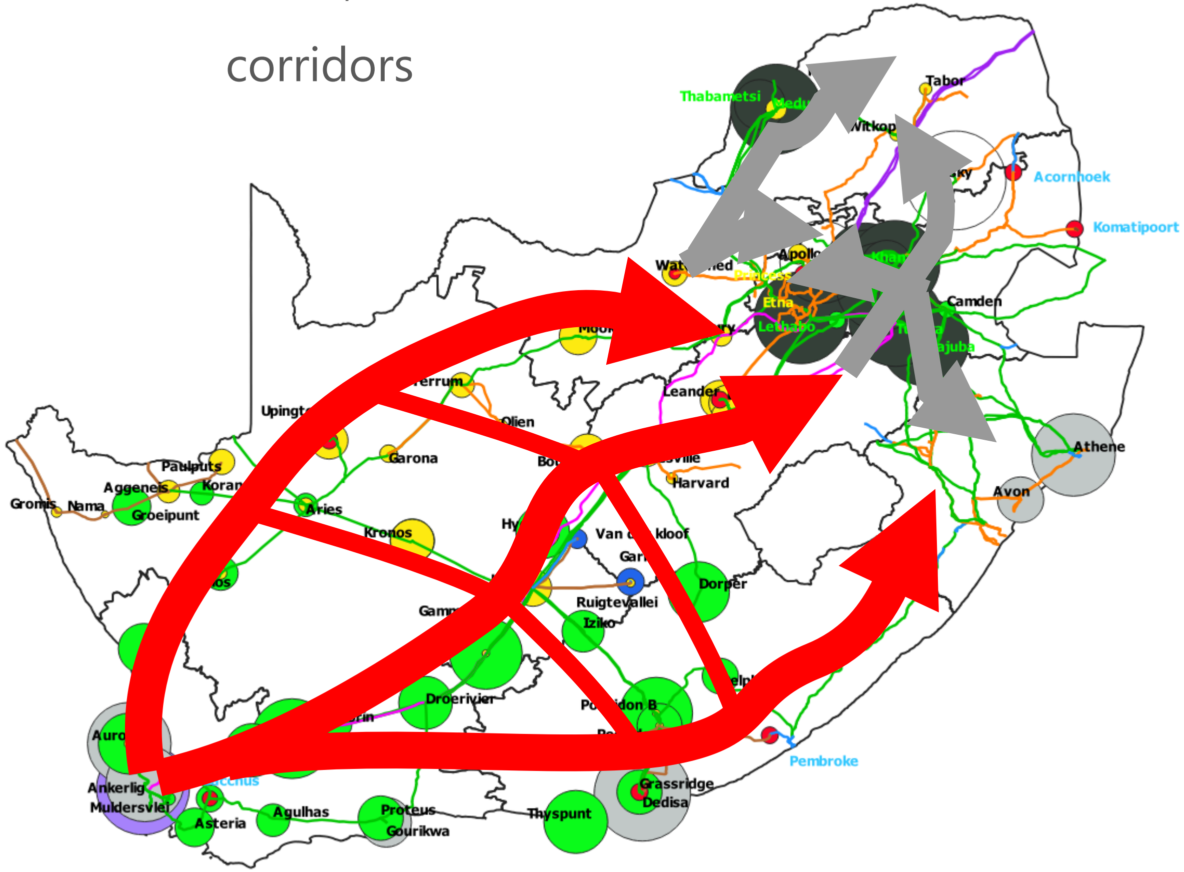
Significant transmission development is required in the northern, central and southern corridors



Lower load in the South remains

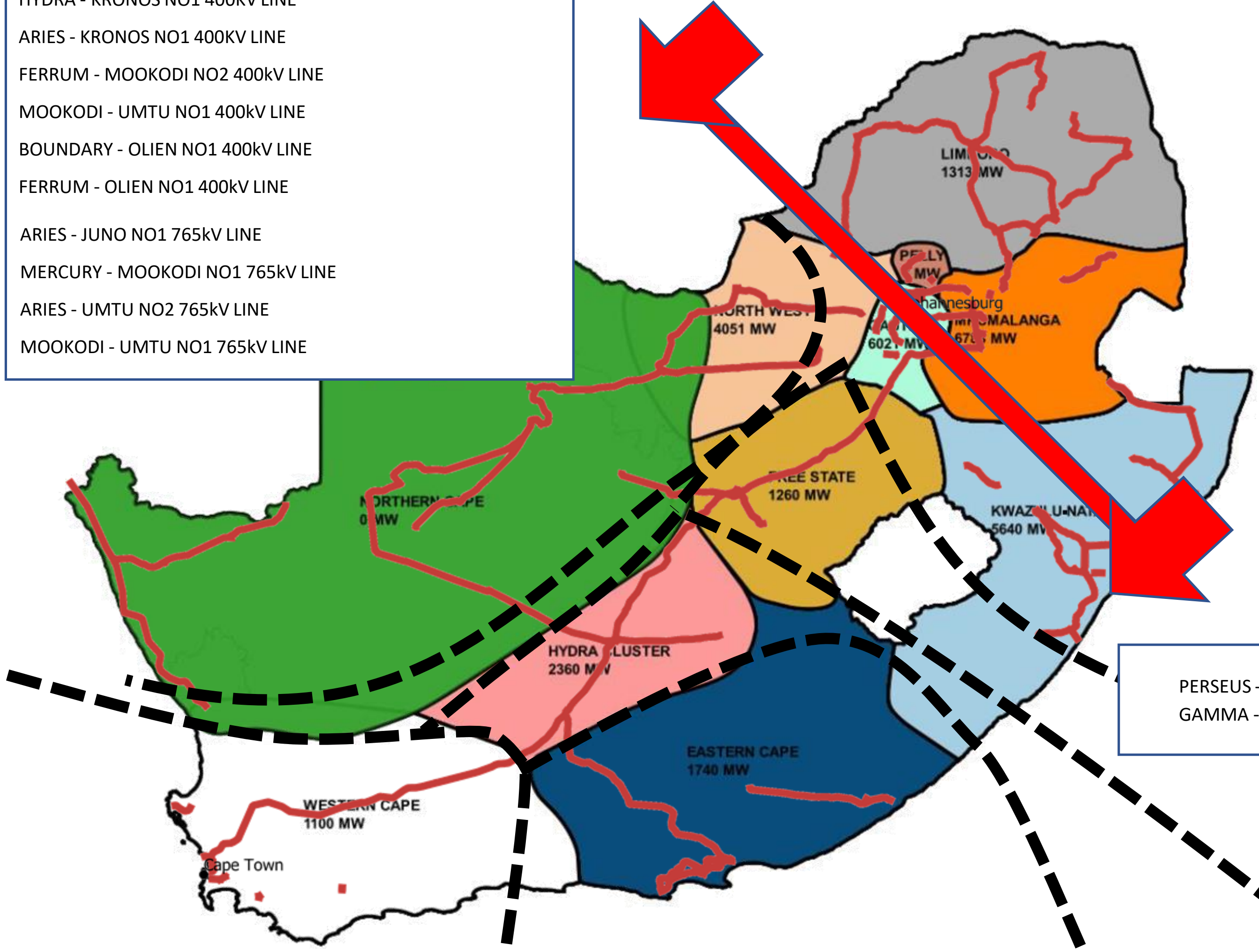


Generation increase in the South



Grid development plans to unlock capacity

HYDRA - KRONOS NO1 400KV LINE
ARIES - KRONOS NO1 400KV LINE
FERRUM - MOOKODI NO2 400kV LINE
MOOKODI - UMTU NO1 400kV LINE
BOUNDARY - OLIEN NO1 400kV LINE
FERRUM - OLIEN NO1 400kV LINE
ARIES - JUNO NO1 765kV LINE
MERCURY - MOOKODI NO1 765kV LINE
ARIES - UMTU NO2 765kV LINE
MOOKODI - UMTU NO1 765kV LINE



Risk of capacity constraints

Limited to ability to construct eg servitudes acquisition + ~3year construction

PERSEUS - ZEUS NO1 765KV LINE
GAMMA - PERSEUS NO2 765KV LINE

GAMMA - KAPPA NO2 765KV LINE
KAPPA - OMEGA NO2 765KV LINE

GAMMA - GRASSRIDGE NO1 765KV LINE
GAMMA - GRASSRIDGE NO2 765KV LINE

GAMMA - PERSEUS NO2 765KV LINE

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https://www.eskom.co.za/eskom-divisions/tx/transmission-lines/transmission-development-plans/

What can be done to unlock capacity until grid strengthening is implemented?

Curtailing dispatchable generation

Is only possible in areas that have existing generation and that does not result in grid instability

The Western Cape presents some opportunity. Studies are currently underway and preliminary results are positive. This may result in increased capacity.

Implementation of storage

Clipping peak congestion with storage is more favorable to PV areas than wind. PV presents a predicable and limited period of congestion. Hence application in the Northern Cape, which is dominated by PV generation is considered. Studies indicate a positive result. However, this can only be achieved with placement of the storage at specific locations.

Voluntary renewable curtailment

IPPs could be connected and peak congestion can be managed with curtailment. This depends on the type of generation and profile. This will be considered on a case-by-case basis.

Increased load in the supply area

Additional load confirmation results in an increase capacity for renewable generation.

Grid stability shall not be compromised.

What factors are leading to blackouts and power shutoff concerns?

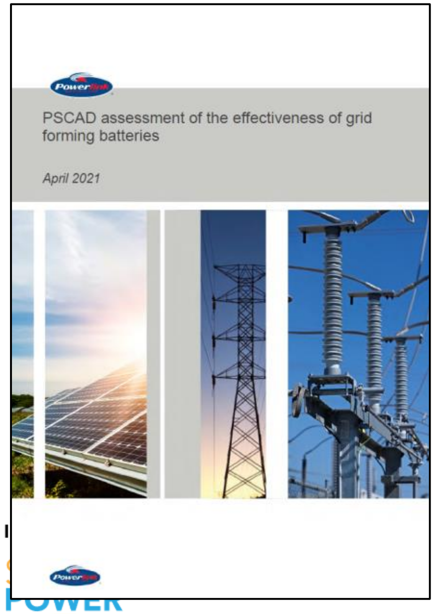
International research and collaboration

- Rapid changes in the transmission of the power system may have unforeseen challenges
- Accelerating learning across system operator and research institutions is critical
- Successful transmission requires active participation of all players including manufacturers, associations, universities, etc

Technology Advancements – Grid-Forming Inverter NREL and ARENA perspective

Present	1–3 years	3–6 years	>6 years
• Early trends in grid-forming applications • Identify research challenges in: • Voltage control • Frequency control • System protection • System recovery • Modeling and simulation.	• Solve research challenges • Develop grid-forming hardware, software, and controls • Develop grid-forming-based grid controls • Lab testing and evaluation • Identify grid-forming integration challenges for demonstration.	• Microgrids to island grids grid-forming demonstration • Solve system integration challenges • Demonstration in weak grids/bulk grid • Demonstrate grid-forming grid controls • Draft standards.	• Establish technical standards for grid-forming • Standardize grid-forming inverter models • Begin adaptation of grid-forming inverters for standard operation in bulk grids.

https://www.nrel.gov/docs/fy21osti/73476.pdf

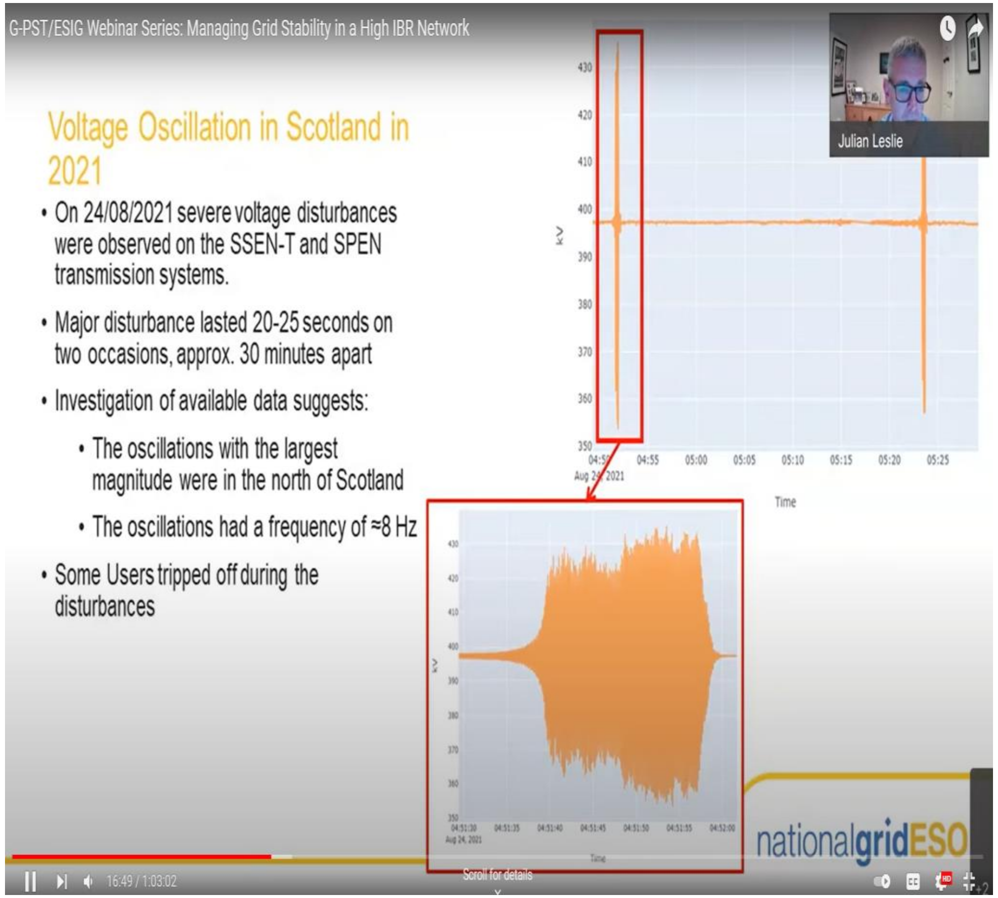


- However, similar to any dynamic device (including synchronous condensers) **they are not a 'silver bullet'** and to be effective, there are a range of factors which need to be carefully considered.
- The thoughtful deployment **of grid forming batteries alongside other technologies will be critical to managing the transition to renewables.**

https://arena.gov.au/knowledge-bank/pscad-assessment-of-the-effectiveness-of-grid-forming-batteries/

- Grid-Forming Inverters are critical to high penetration weak grids like South Africa
- Still under development by many manufacturers
- No international standards exist
- Manufactures have their own interpretation of a Grid-Forming inverters

Unforeseen challenges in Scotland - similarity to the South Africa System



https://www.youtube.com/watch?v=OyGCB3FV5Pw&t=1252s

- System strength "short circuit" is declining over the entire system
- Unlike South Africa the inertia in Great Britain remains high (as was in this event)
- Low synchronous generation with high inverter penetration - System oscillations were observed by the system operator for an extended period.
- Various generation plant tripped (correctly) from the oscillation wide impact
- ROOT CAUSE UNKNOWN - Short term more synchronous generation online
- Finding the root cause requires developing more detailed EMT model.
- Identified need to update the Grid Code for improved modeling requirements

Islanded networks – high penetration Grid-Forming Inverters –

Hawaiian Grid Forming Inverter (GFI)

South Africa can be considered as an islanded network

Learning from the Hawaiian studies provided insights into what challenges need to be considered and overcome.

Hawaiian Electric in collaboration with manufacturers and consultants investigated 100% GFI

Hawaiian Electric

RFP Stage 2 IRS
Island-Wide PSCAD Study

IGP Working Group

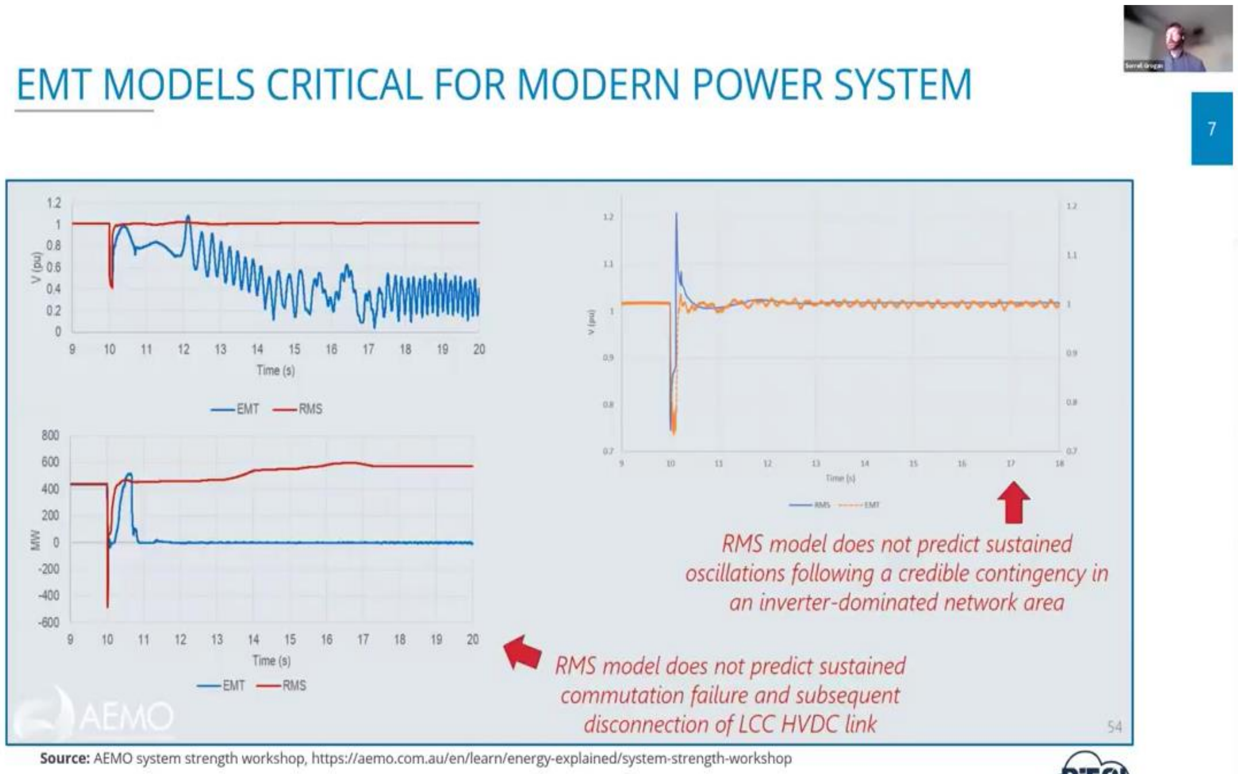
June 30, 2020

https://www.hawaiianelectric.com/clean-energy-hawaii/integrated-grid-planning/island-wide-pscad-study-meeting-june-30-2021

- The aggressive inverter-based renewable penetration scenarios are **beyond what is considered well understood in the industry**.
- These studies are accordingly **unusually complex**, with **many important and in some cases untested assumptions built in**.
- In addition, some of **the equipment being proposed is conceptually new and untested**
- There is **unavoidable uncertainty both in completing the studies to a schedule and in impact on future power system reliability**

Need for greater modeling complexity, more detailed Grid Code models required, greater interaction with manufacturers for tuning and upfront testing of technologies.

AEMO (Australia) - Large Islanded network high penetration



https://www.youtube.com/watch?v=U5sgMMj1Ico&t=146s

High penetration requires high resolution of modeling to observe system stability and inverter interaction

- Current transient analysis tools (RMS) are failing in high penetration inverter dominant networks.
- Under fault conditions the “RMS tend to overestimate how well things are going to be”
- RMS show system will return to a stable condition the EMT shows network will collapse.
- Greater congruence between the EMT and infield measurements.
- Analysis must shift to EMT models
- EMT needs the real source code compiled into the EMT, to better represent the interaction with the system and other inverter
- Cannot evaluate independently of other plant

- Electricity system will adapt to high-renewable generation but requires time and money for the large grid expansions

- Grid Code and modeling techniques need adaptation to ensure stable operation

- Increased collaboration from all parties, international and local research, manufacturers, renewable association is required to ensure improved Grid Code, inverters technologies modeling / integration / compliances and updates.

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