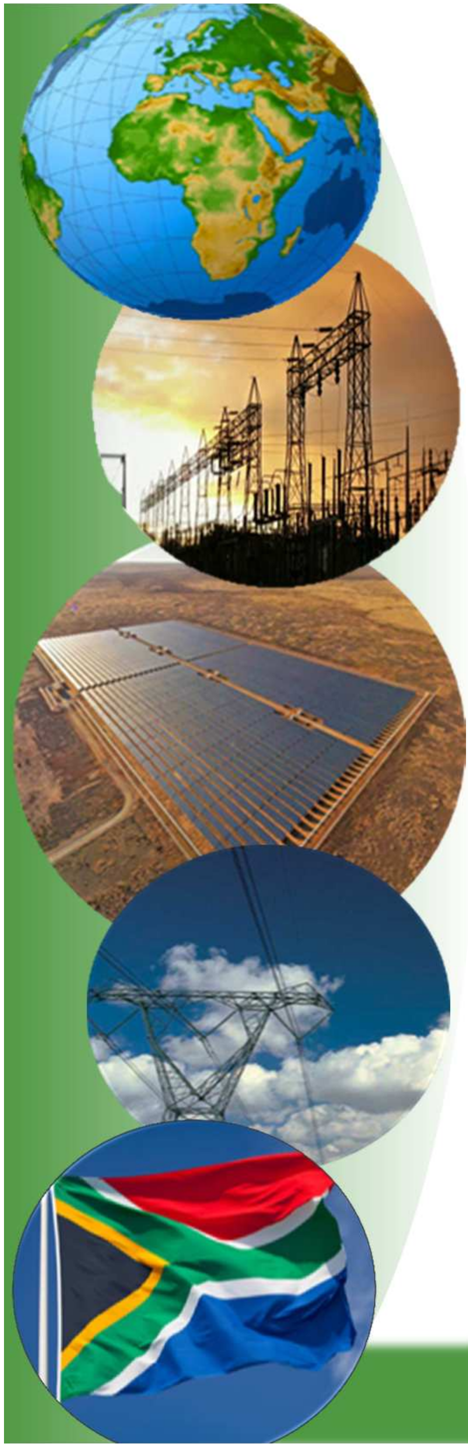

Use of Thyristor Controlled Series Capacitors (TCSCs) to enhance power system transient stability and their possible application on Transmission Grids of developing economies

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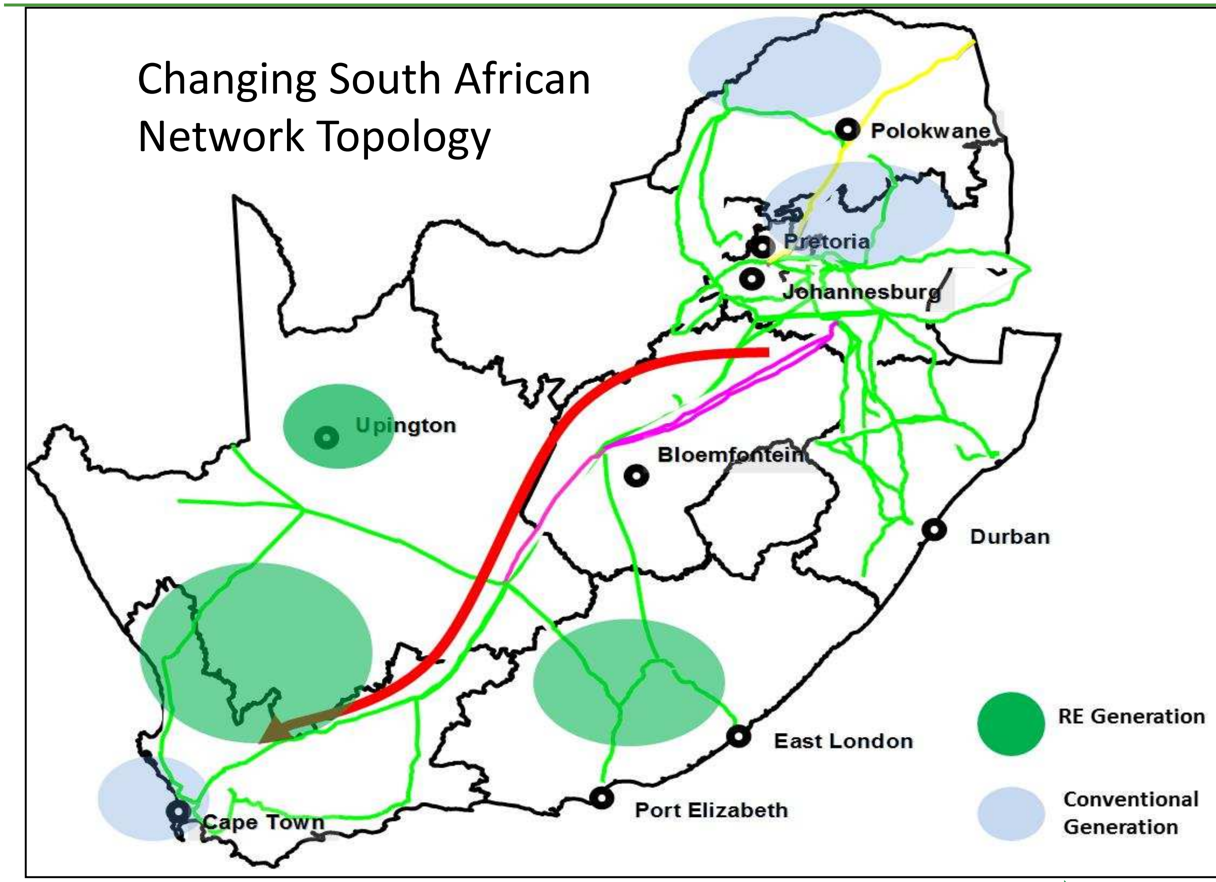
Introduction

Changing South African Network Topology



Active power transfer bottlenecks:

- poor oscillation damping
- transient instability

Solutions:

- Use transformers with lower reactances
- Building additional lines
- Line series compensation

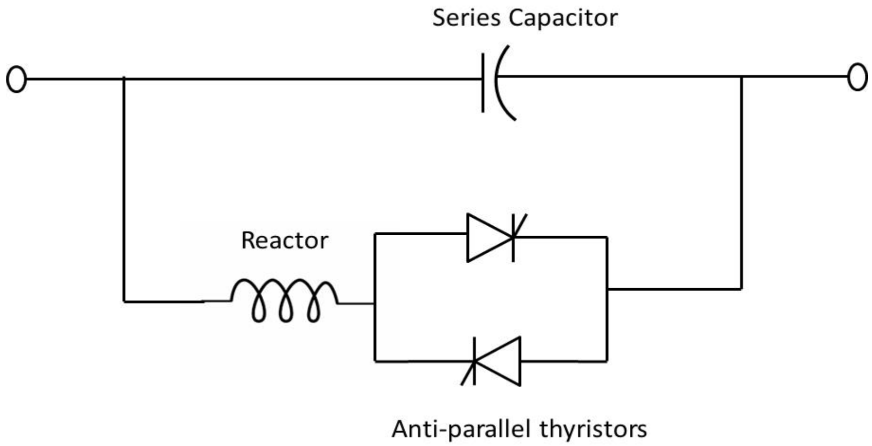
Sub-synchronous resonance (SSR) risks near thermal generators.

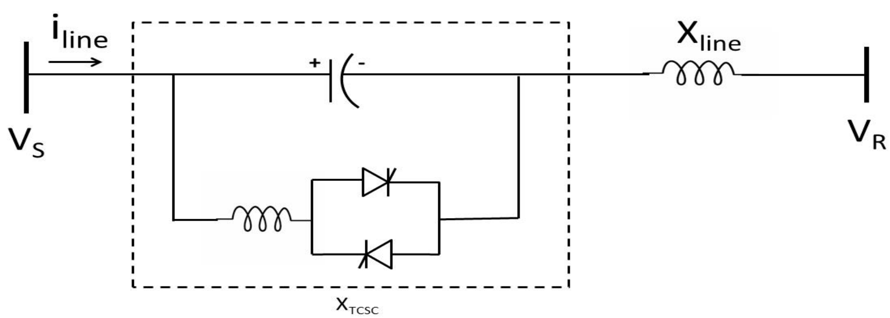
Thyristor Controlled Series Capacitors (TCSCs): higher levels of series compensation possible

Global trend: migration to dispersed renewable energy

Case still exists for long distance transmission of generated power

TCSC Principle of operation





Higher levels of compensation possible vs fixed series capacitor

Components:

Thyristor controlled reactor (TCR) in parallel with the fixed capacitor.

Operation:

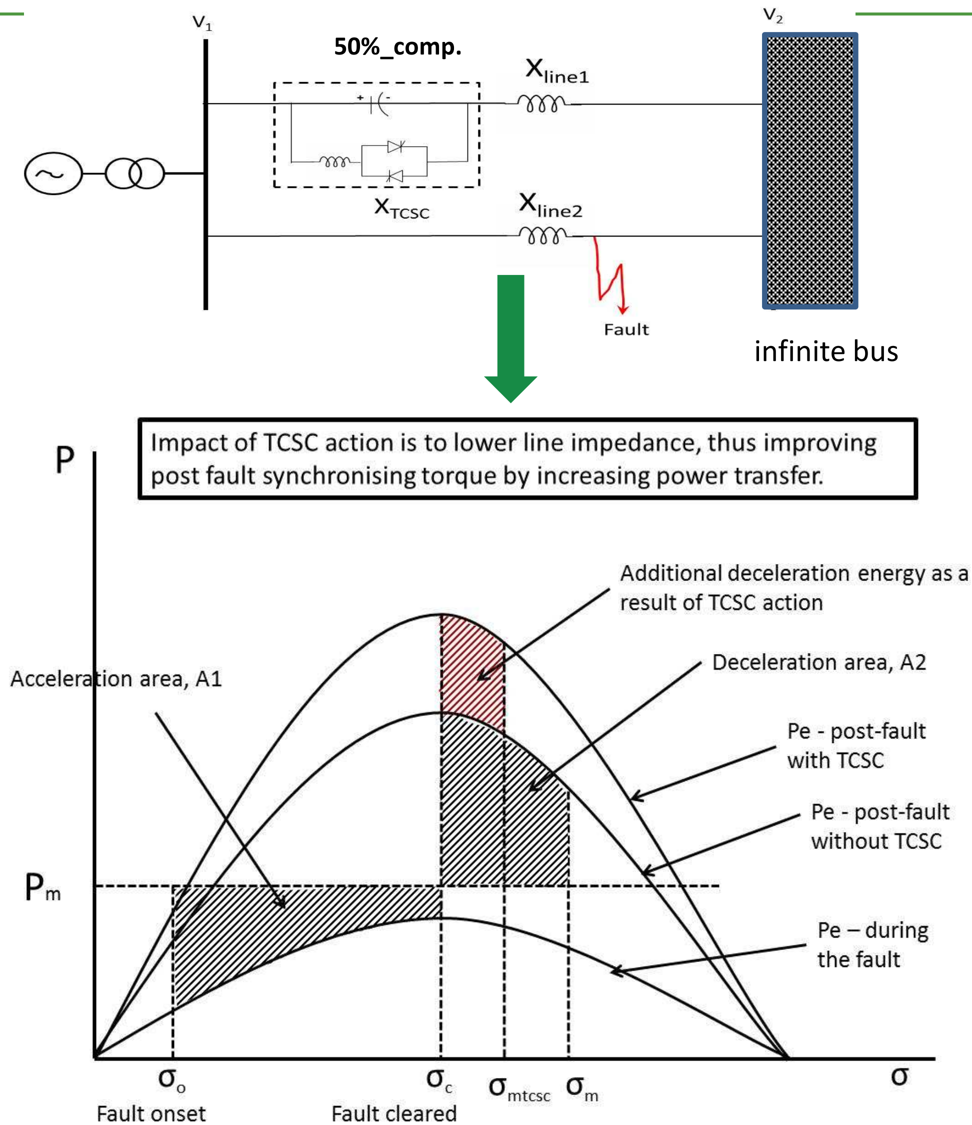
The inductive reactance is varied by the firing angle, α of the thyristors.

$$P_{SR} = \frac{V_S V_R}{X_{line} - X_{TCSC}} Sin\delta_{SR}$$

Vital functions:

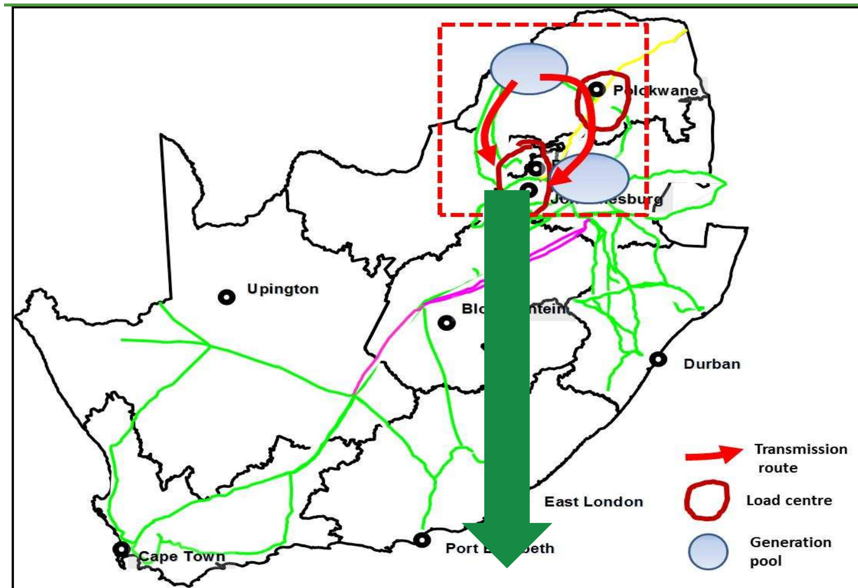
- Damping of active power oscillations
- Post-contingency stability improvement: improves power transfer (reduced eff. line impedance).
- Elimination of SSR risks: makes series capacitor(s) act inductive in the sub-synchronous frequency band (occurrence of series resonance is prevented)

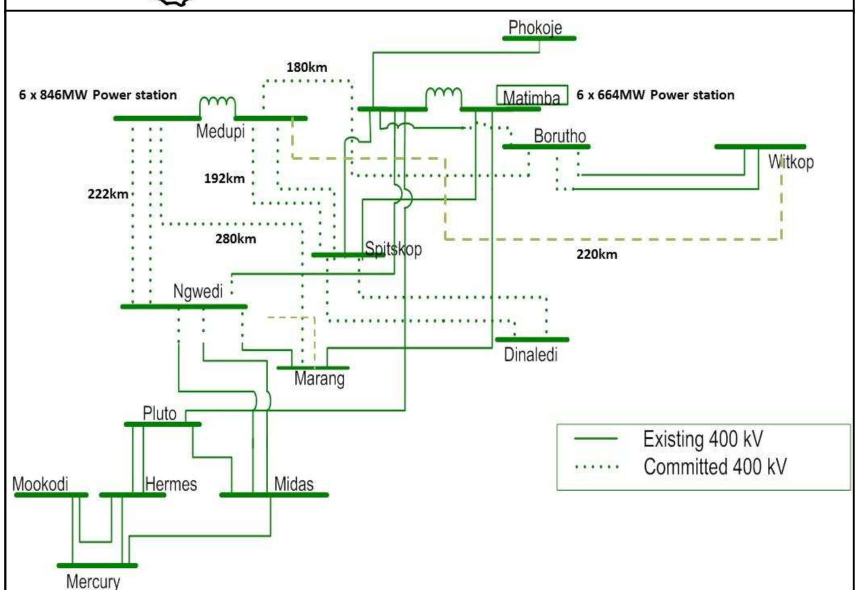
TCSC impact on transient stability



- Generator supplying an infinite bus via two connected transmission lines, with one of the transmission line series compensated using a TCSC.
- The TCSC action is illustrated by a three phase fault simulated on a line without a TCSC and the fault is cleared by tripping the faulted line.
- The TCSC would be triggered to regulate levels of compensation on the remaining line, in order to improve its power transfer capability and improve stability of the generator

Case Study – SA northern gen. pool





- Determine transient stability margins for Medupi three phase line faults with and without TCSC;
- Select the transmission line with most benefit from TCSC application;
- Vary the degree of compensation on the selected line and establish the effect on stability margins; and
- Compare use of a TCSC to addition of a new line that results in the largest stability margins.

Case Study Results

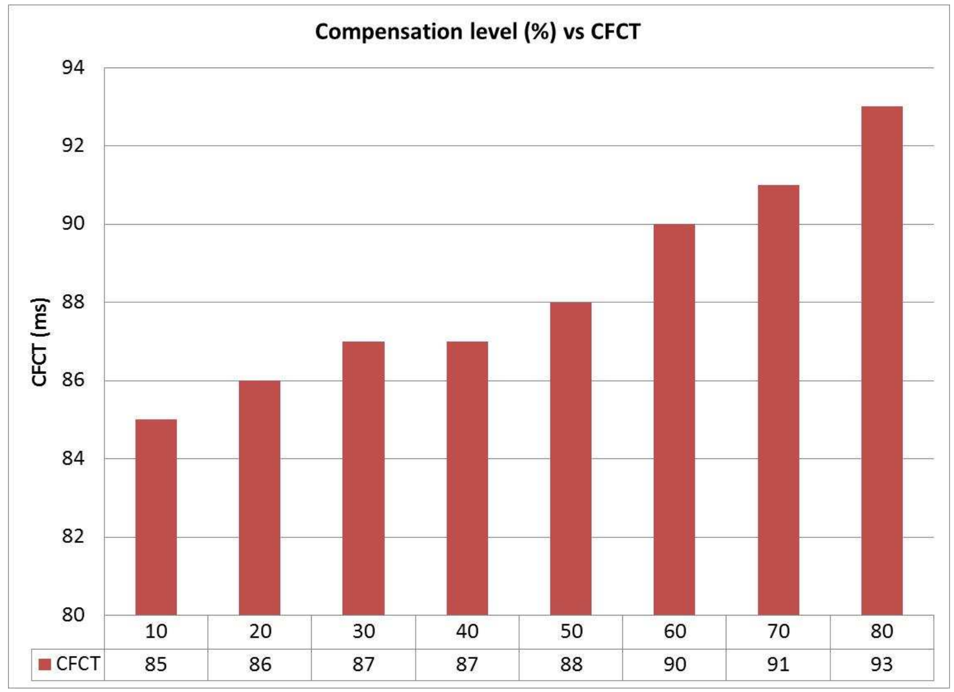
Three phase line faults simulated **without TCSC** applied and critical fault clearing times (CFCTs) determined:

Faulted line	CFCT (ms)
Medupi – Witkop 400 kV line	85
Medupi – Marang 400 kV line	90
Medupi – Spitskop 400 kV line	87
Medupi – Borutho 400 kV line	84
Medupi – Ngwedi 400 kV line	88

Most onerous line fault

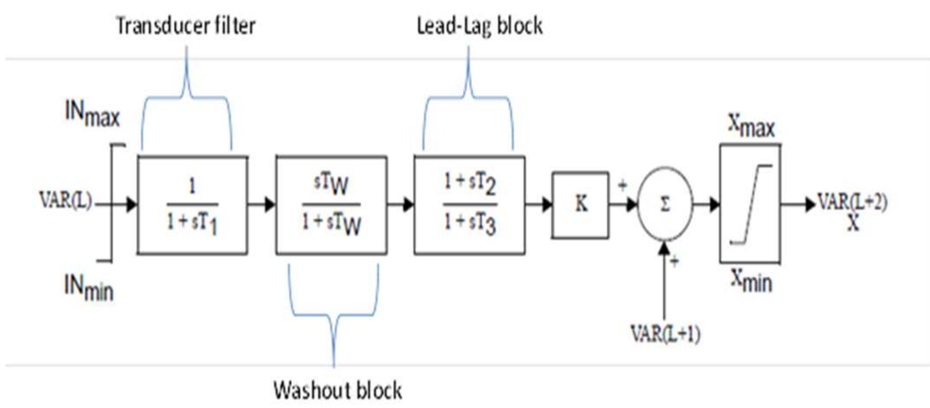
Principle: compensate line with largest CFCT

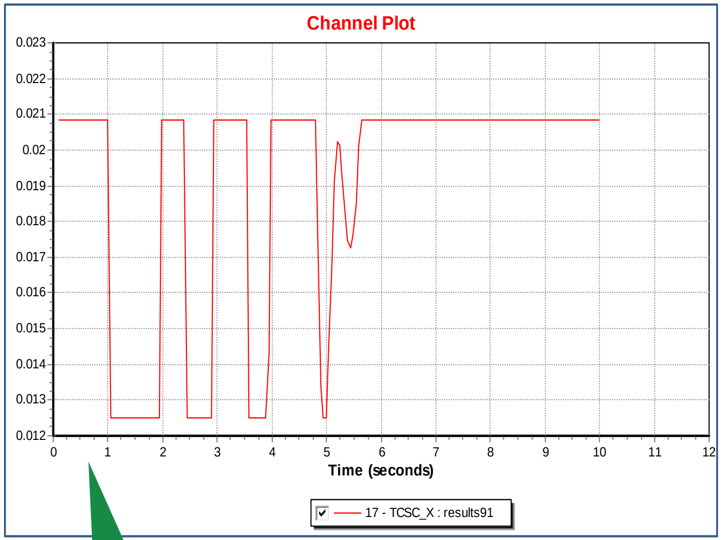
Series compensation (varying levels) applied on the Medupi – Marang line and faults applied on Medupi – Borutho line (intention is to lift the critical line):



Steady increase in transient stability margin with increase in series compensation level.

TCSC Modeling (in PSS/E) and Results





- IN_{max} and IN_{min}, which are maximum and minimum (pu) input signals/limits, respectively. (inputs: bus voltage, machine speed deviation, etc)
- K is the gain
- X_{max} and X_{min}, which are (pu) maximum and minimum output (line reactances), respectively.
- T_1, T_w and T_2, T_3 are time constants for the transducer filter, washout block and lead-lag block, respectively.

The Medupi – Marang line reactance (TCSC_X) is reduced by TCSC action to enhance stability

Comparison of TCSC and additional line

Additional lines (one at a time) added in parallel with existing lines and faults simulated on Medupi – Borutho line:

Additional lines	CFCTs (ms)
2nd Medupi – Witkop 400 kV line	90
2nd Medupi – Marang 400 kV line	87
3rd Medupi – Spitskop 400 kV line	88
3rd Medupi – Ngwedi 400 kV line	87
2nd Medupi – Borutho 400 kV line	91

Comparison based on environmental impact, technical and financial merits:

Description	2nd Medupi – Borutho 400 kV line (180 km)	TCSC (70%) on Medupi Marang line
Environmental impact	assessment over two years	within a year
Servitude acqusition	over 3-5 years	within a year
Building period	~ 2-3 years	~ 1-2 years
Technical feasibility	established alternative	new in most developing countries
Capital cost	costly ~ 800 ZAR M	cost effective ~ 650 ZAR M

Additional line resulting in largest stability margin

Correspond to 70% series compensation

Minimise TCSC cost (50% fixed, 20% dynamic)

CFCT increase to 91ms enabled approx. 500 MW new generation

Conclusions

- Short lead times for servitude acquisition and construction enables a fast – response strategy;
- TCSC enables required capacitive compensation levels near thermal generators, due to its ability to eliminate SSR risks;
- TCSC application can enable incremental generation connection in areas limited by transient instability;
- TCSCs are viable alternatives to address above system problems where funding constraints exist.