High penetration of renewable resources and the impact on power system stability

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Outline

- Introduction
- Discussion of case studies
  - South Australia – system event of September 2016
  - System Study – integration of up to 200 MW of wind to the Sri Lankan Grid

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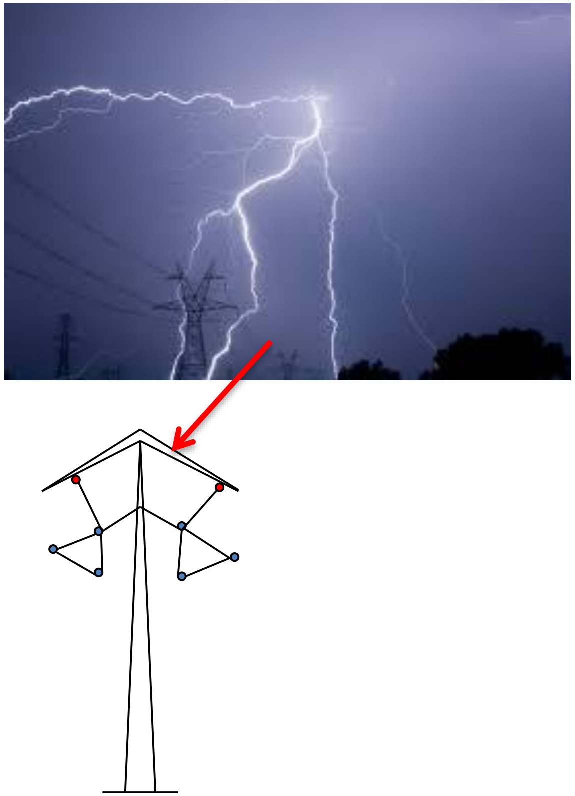
Introduction

- Power systems are designed to ride through credible system events such as faults, load rejection and generator tripping.
- Due to diligent planning process involved, major disturbances that lead to wide spread power outages are rare.
- However, major event do occur and on most situations, the such events are triggered by 'highly improbable' events.



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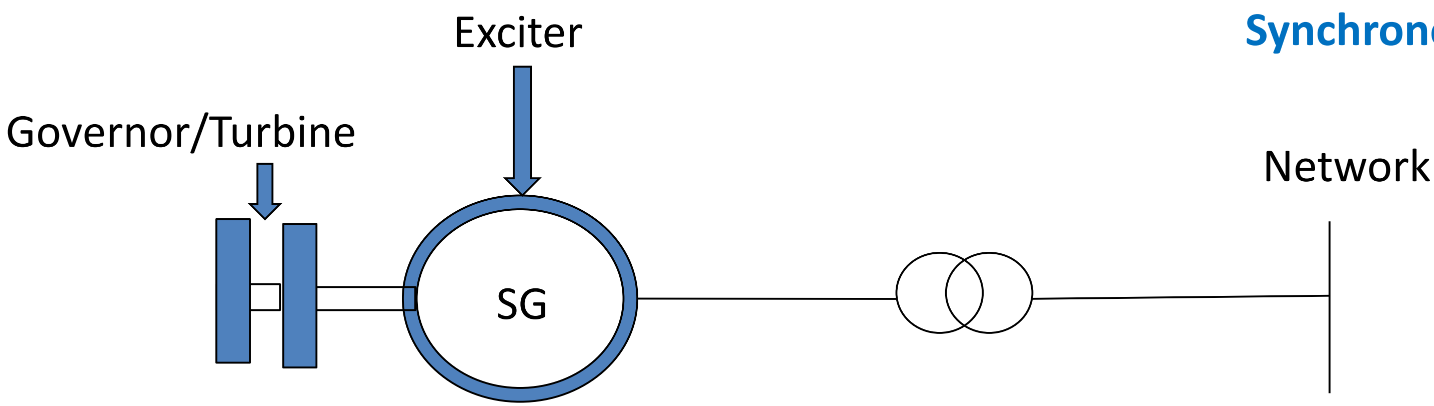
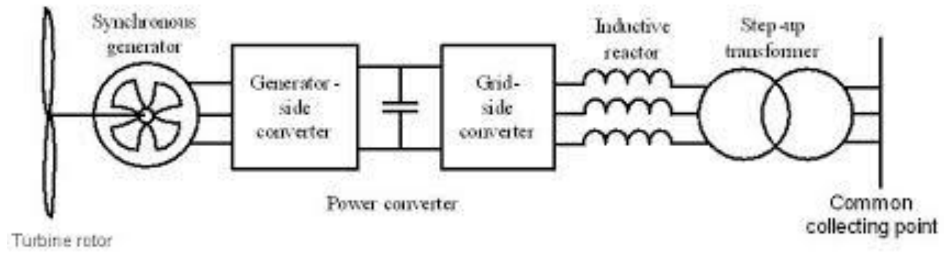
Impact of Wind Generation on System Inertia and Stability

Synchronous Generator



Wind Generator (T4)



Introduction

- Modern transmission level wind and solar PV generation are interfaced to the grid through power electronic converters.
  - The characteristics are much different from the conventional synchronous machines.
- The kinetic energy associated with rotating masses of conventional generating units act to provide inertial support to the system.
  - natural response of the machine and does not depend on activation of protection and control functions.
  - Power electronic based wind and solar PV generators do not provide the same levels of inertia as the conventional generators.
- This can have a significant impact on system frequency stability when renewable penetration in a region becomes significant.

Example 1 – Black System South Australia – September 28, 2016

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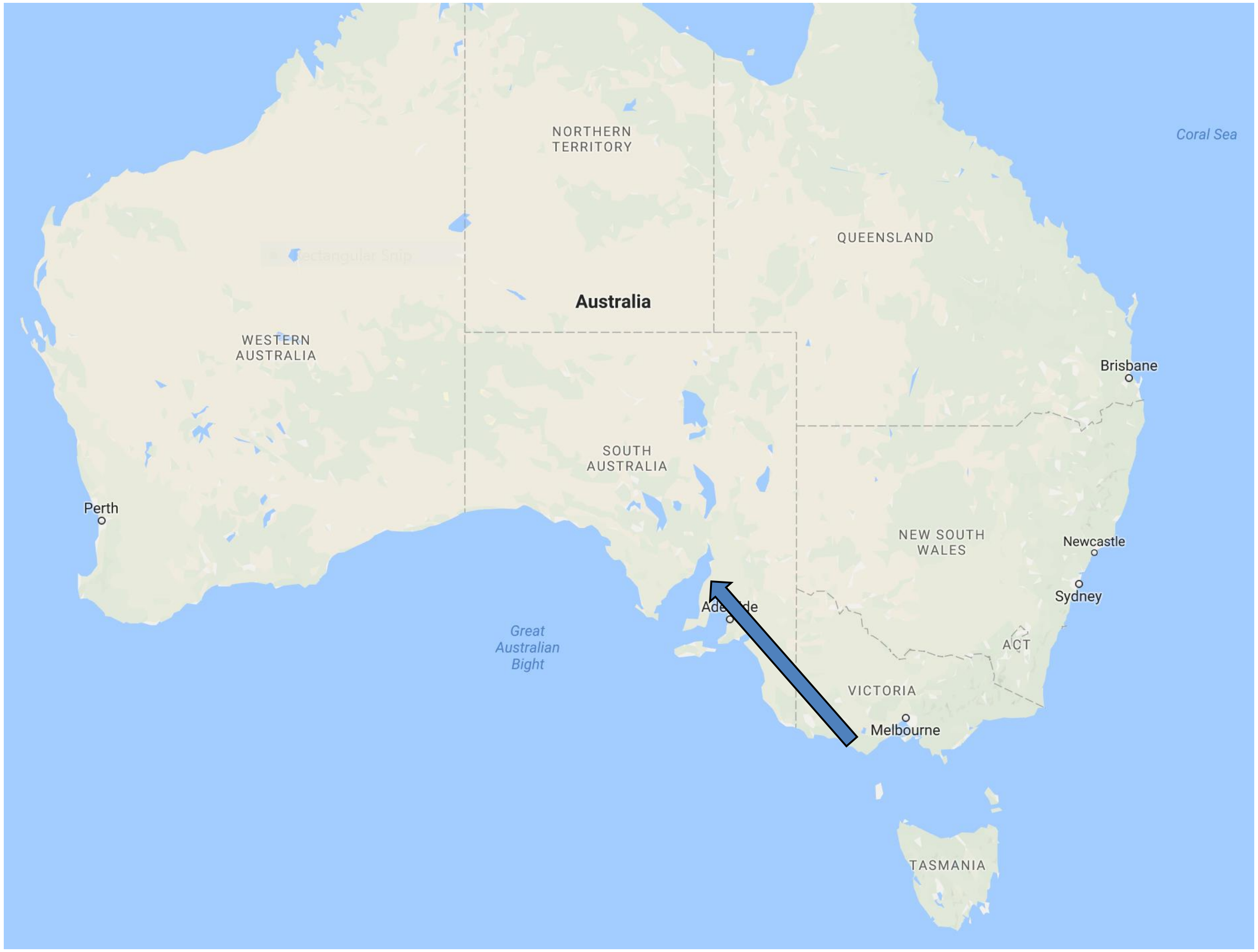
Event Description



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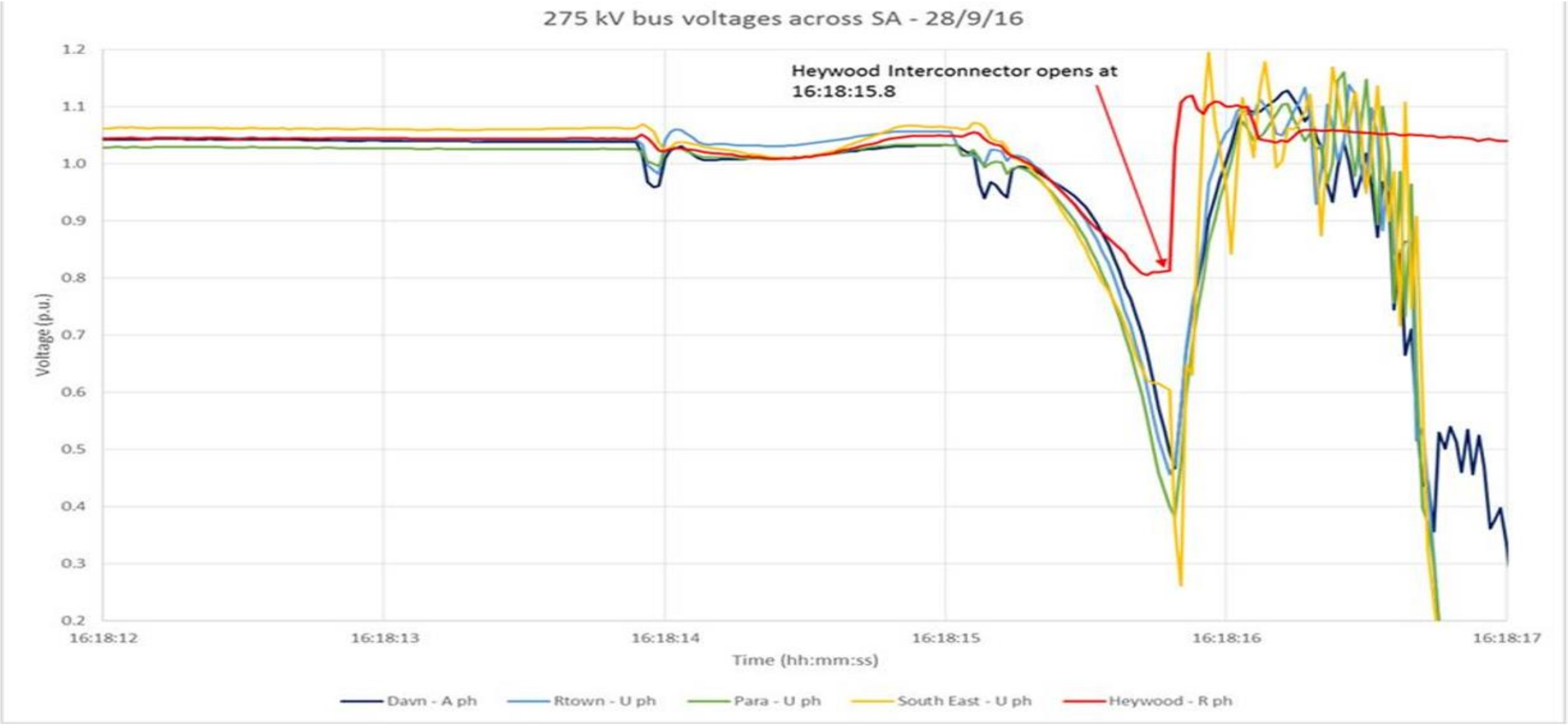
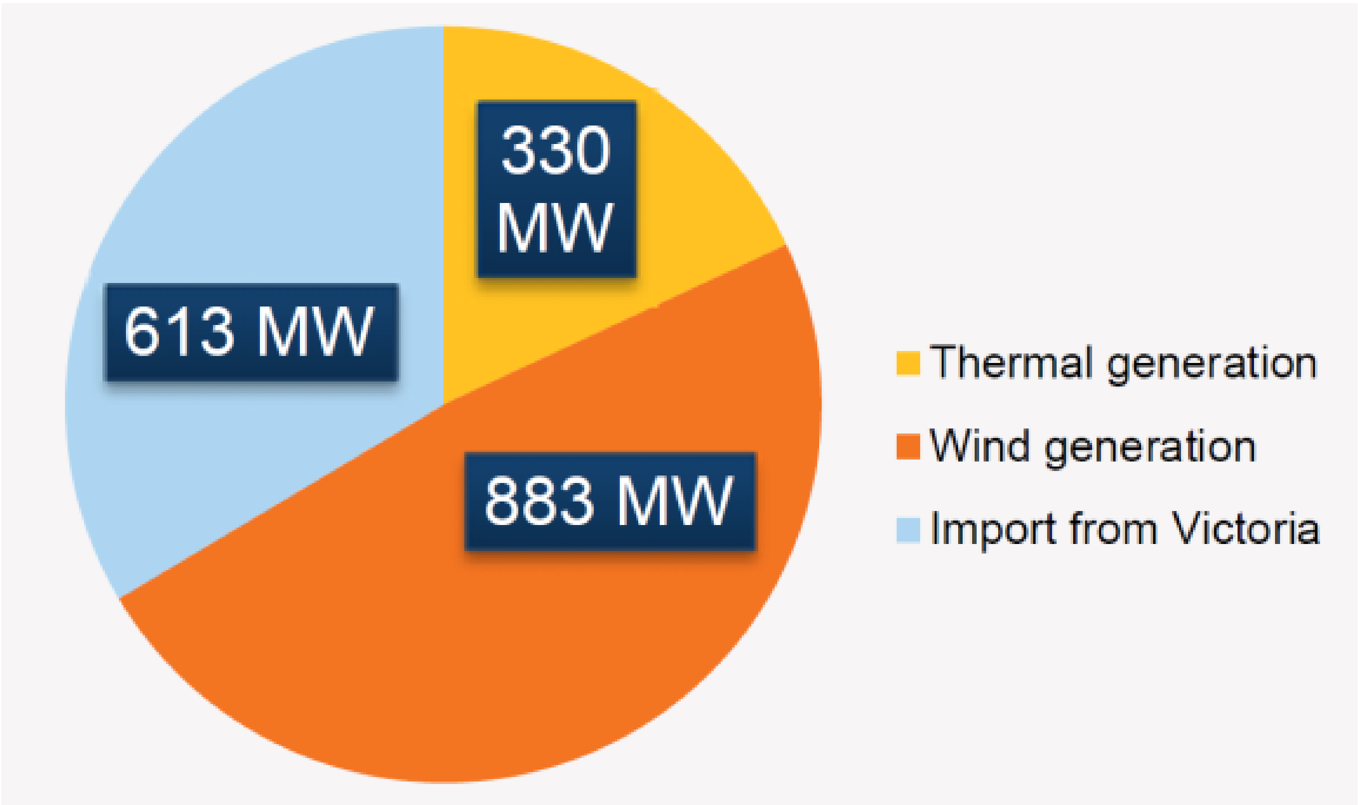
Event Description



South Australia – Generation mix prior to event



Event Description

- Extreme weather conditions resulted in five system faults on the SA transmission system in the 87 seconds between 16:16:46 and 16:18:13, with three transmission lines ultimately brought down

- In response to these faults, and the resulting six voltage disturbances, there was a sustained reduction of 456 MW of wind generation to the north of Adelaide.

- Increased flows on the Heywood Interconnector counteracted this loss of local generation by increasing flows from Victoria to SA

- This reduction in generation and increase of imports on the Interconnector resulted in the activation of Heywood Interconnector's automatic loss of synchronism protection, leading to the 'tripping' (disconnection) of both of the transmission circuits of the Interconnector. As a result, approximately 900 MW of supply from Victoria over the Interconnector was immediately lost.

Event Description

- This sudden and large deficit of supply caused the system frequency to collapse more quickly than the SA Under-Frequency Load Shedding (UFLS) scheme was able to act.

- Without any significant load shedding, the large mismatch between the remaining generation and connected load led to the system frequency collapse, and consequent Black System.

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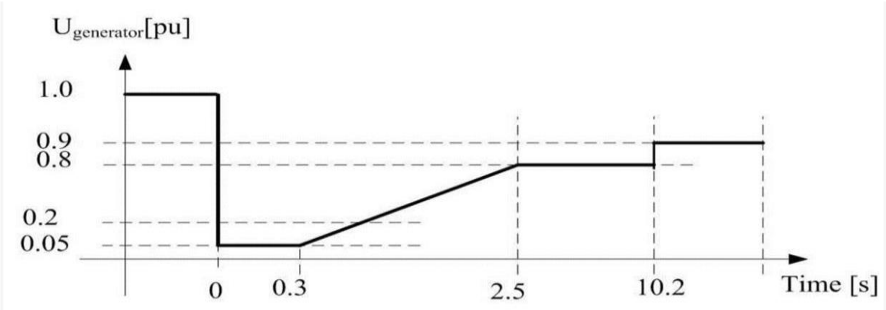
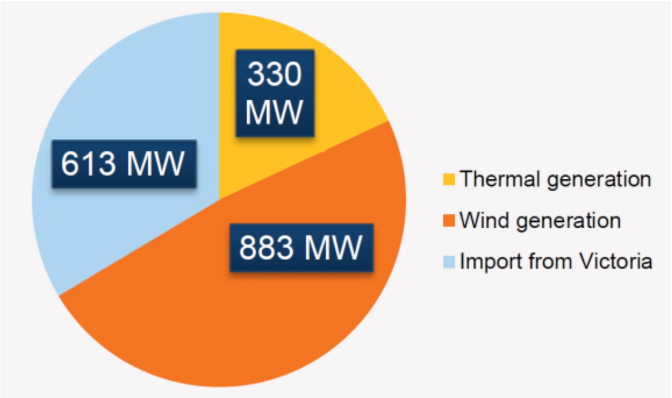
Fault ride through requirements of wind farms

- All wind farms met the ride through requirement for the number of faults within the short duration

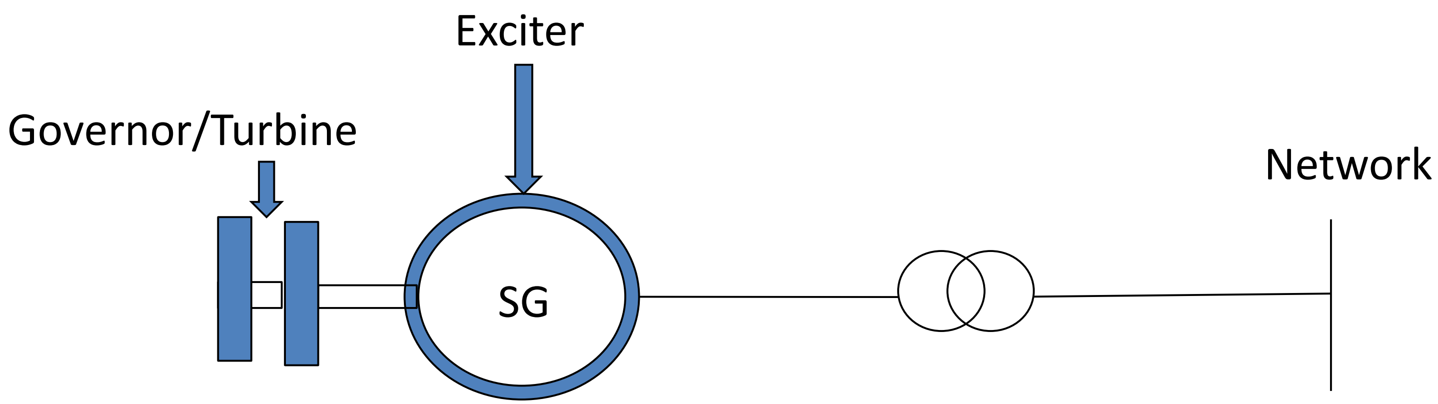
- However, an additional protection that was not known to system operators got activated to trip some of the wind farms (more than 3-4 faults experienced within a pre defined short duration)



Source: Vestas Wind Systems A/S. *Advanced Grid Option 2, Vestas VCS turbines*, 2011.

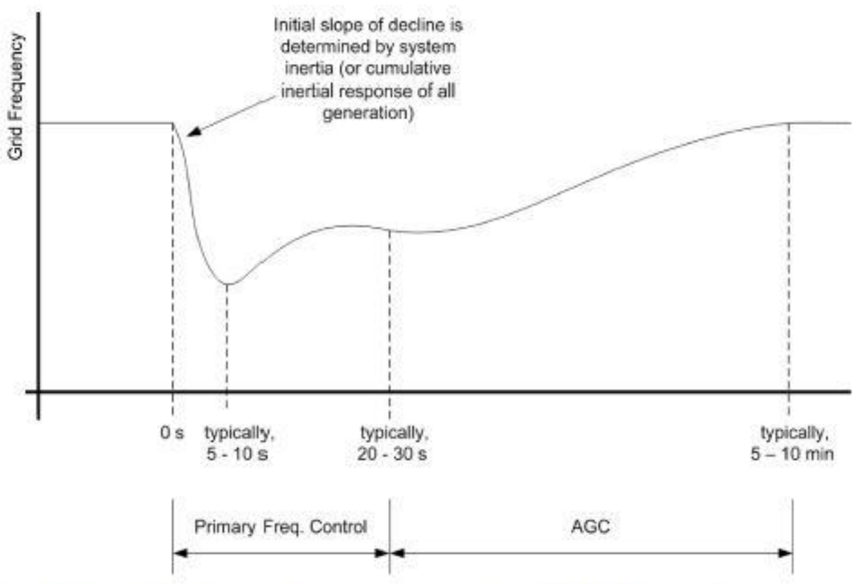


Characteristics of Synchronous Generators



- The Synchronous generator response is determined by
  - Machine electrical characteristics
  - Exciter characteristics
  - Governor / turbine
  - Inertia of the rotating masses

Characteristics of Synchronous Generators



- The inertial response immediately follows the event
- Primary control - 20 -30 Sec
- Secondary - 5 -10 minutes.
- The inertial response is due to the inertia of large synchronous generators

Lessons Learned and Recommendations

Generation Mix and System Inertia:

- The system inertia on the SA side was not sufficient to maintain the frequency drop (once the Haywood interconnector tripped) and to make the under frequency load shedding (UFLS) effective.

- ‘Must run’ thermal generation may have to be identified.

- Synchronous condensers may be investigated as a potential solution if the thermal generation dispatch is expected to be low under specific load conditions.

Lessons Learned and Recommendations

Under Frequency Load Shedding:

- The under frequency relays do not start activating until the frequency drops to 49 Hz. The effectiveness of this scheme may have to be re-visited even if the SA side inertia is increased through thermal generation dispatch.

UFLS should be the first line of defense.

Special Protection Schemes:

- In our opinion, special protection (SPS) should be considered if UFLS does not provide the required system security. AEMO identify this in Section 3.6.

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System Studies – Model Validity

Reference

BLACK SYSTEM SOUTH AUSTRALIA 28 SEPTEMBER 2016 - Report by AEMO
www.aemo.au

Example 2 – Integration of 200 MW wind to a relatively small power network

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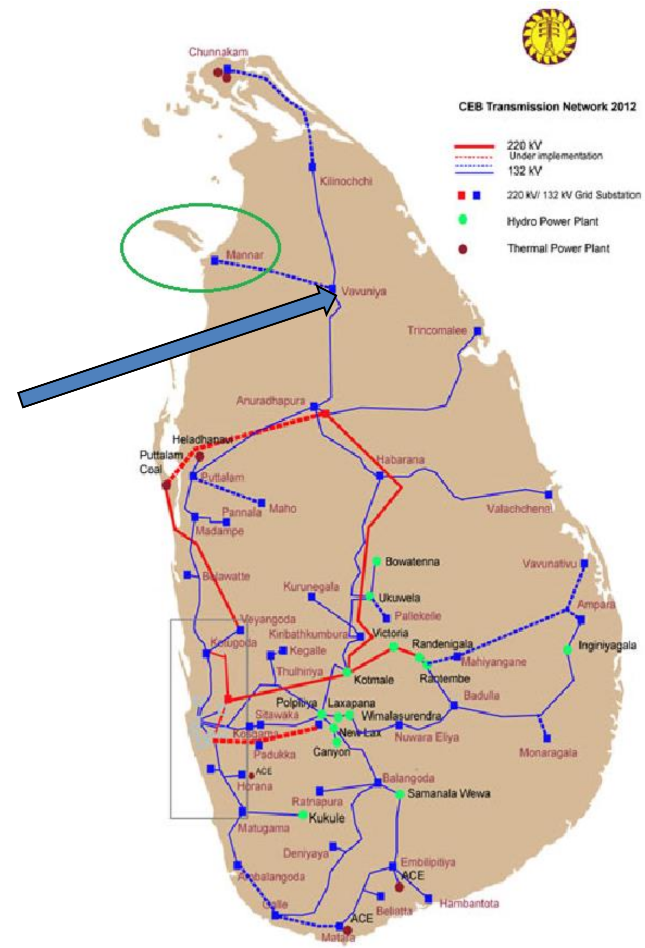
Integration of 200 MW wind in North West region of Sri Lanka – Studies to support the renewable energy Master Plan

- Technical Feasibility of integrating a significant amount of renewable energy to a relatively small power network.
  - Load flow studies
  - Dynamic stability studies
  - Wind farm fault ride through studies



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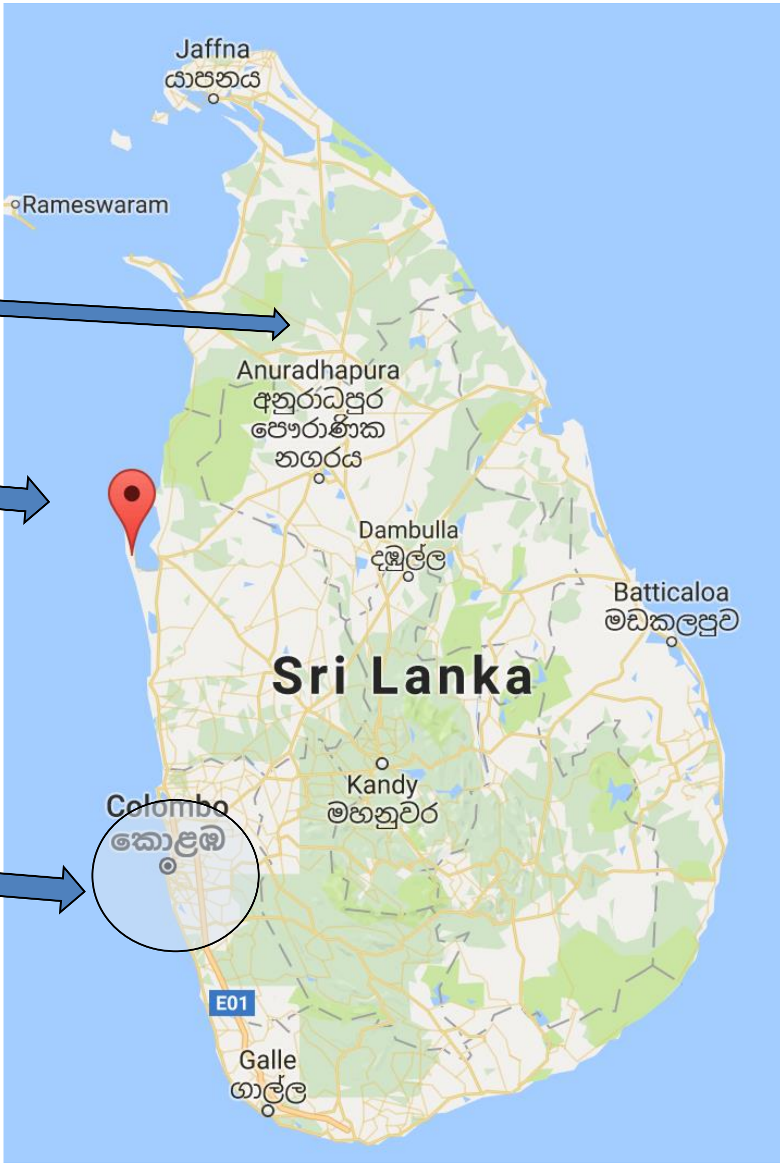
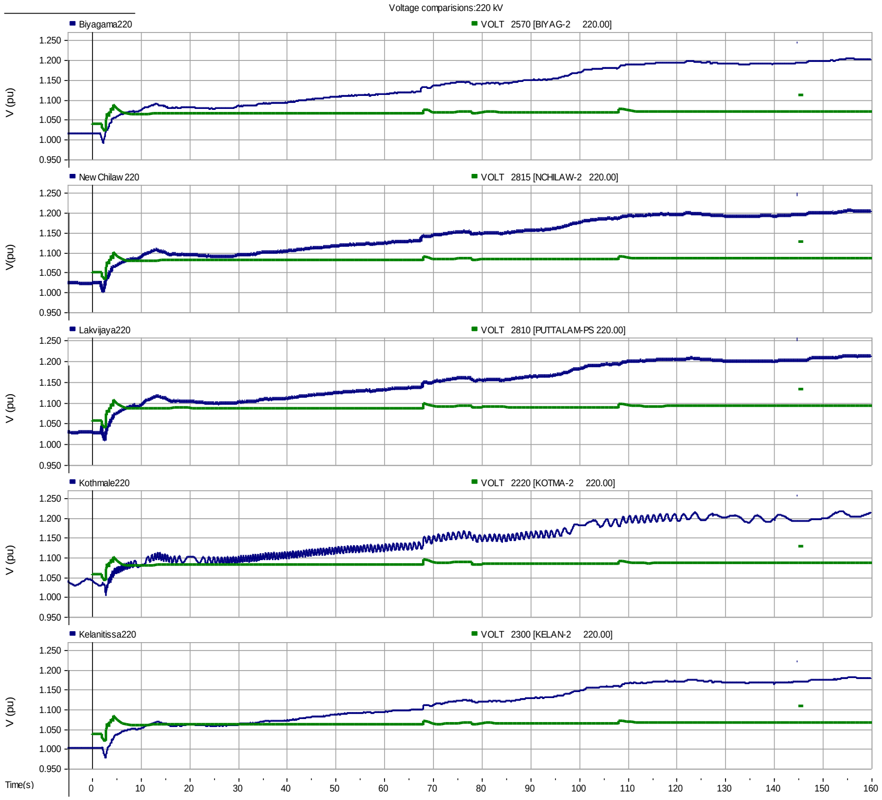
Operation of the Sri Lankan System – Event of September 2015

- The event occurred during a time when the system load was unusually low (800 MW)
- A coal Generation unit delivering approximately 280 MW (33%) and absorbing 28 MVAr tripped due to a protection malfunction.
- The major load centre is around the capital city.



Comparison of field data with simulation results – Event of September 2015



- System Voltage: Recorded (Blue) and Simulation (Green).
- The simulation model does not capture the event accurately.
- Model predicts excellent voltage control:
  - Are tap changer actions adequately modeled
  - Are the remaining generators providing the expected voltage support

Studies and Study Scenarios

Load flow studies

Dynamic simulation

PSS/E dynamic stimulations are performed to identify violations of dynamic performance criteria for a set of selected disturbances.

Study Scenarios Analyzed

- 2017 Hydro Maximum Day Peak (DH)
- 2017 Hydro Maximum Night Peak (DN)
- 2017 Thermal Maximum Day Peak (DT)
- 2017 Thermal Maximum Night Peak (NT)
- 2017 Off Peak (OP)

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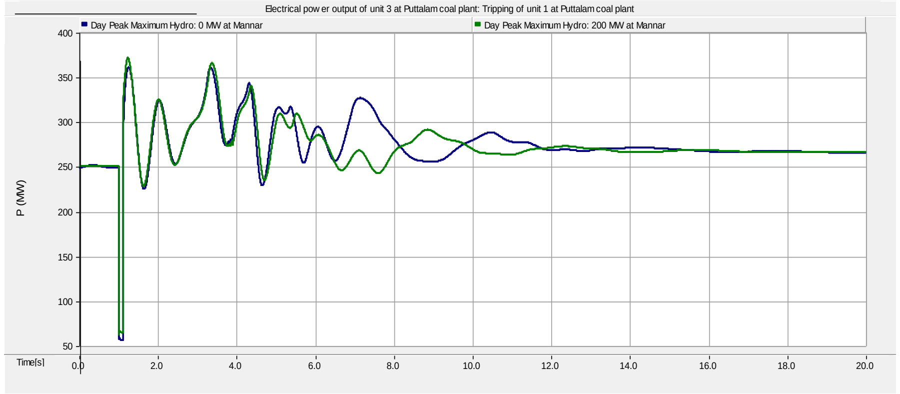
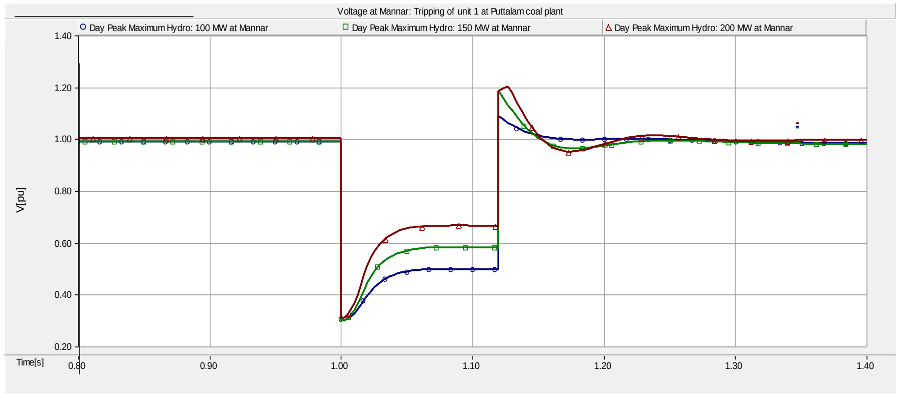
Results





System Data – Model Uncertainties

Bus Number	BUS Name/Machine Id	Base kV	Mbase[MVA]	Pmax[MW]	H, Inertia
1300	KELAN-1 / 1	132	88	75	8
1300	KELAN-1/ 3	132	135	115	8
2300	KELAN-2 /1	220	122	104	4
2300	KELAN-2 /2	220	72	61	4
2300	KELAN-2 /3	220	128	109	8
2300	KELAN-2 /4	220	64	54	4
2305	KERAWALA_2 /1	220	70	113	7.253
2305	KERAWALA_2 / 2	220	70	113	7.253
2305	KERAWALA_2 /3	220	33	54	4.469
2305	KERAWALA_2 /4	220	62	150	7.253
2305	KERAWALA_2 /5	220	65	105	7.253
2400	HAMBA-2 /1	220	353	300	8
2400	HAMBA-2 /2	220	353	300	8
2725	SAMPOOR-1 /1	220	294	250	4.376
2725	SAMPOOR-1 /2	220	294	250	4.376
4810	PUTTA_G1 /1	20	335	275	4.376
4811	PUTTA_G2 /1	20	335	275	4.376
4812	PUTTA_G3 /1	20	335	275	4.376

Conclusions

- Single unit tripping at Puttalam coal power plant was identified as the worst dynamic disturbances before the integration of Mannar wind farm.
- Activation of the under frequency load relays were observed.
- In addition, insufficiently damped (oscillations approximately around 1 Hz continues for over 10 s) power swings in the system under certain dispatch conditions were observed.
- After the integration of Mannar wind farm (up to 200 MW), the same contingency (i.e. tripping of one unit at Puttalam) remains the worst contingency and wind farm has no impact on the fault recovery performances.
- Sensitivity studies formed a integral part of the study to eliminate concerns related to accuracy of system model data.

Thank you

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