FRT Protection Settings

Damian Jackman

Introduction

- South Australia Blackout Event
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  - Storm passage and Fault Ride Through Events
  - Loss of Wind Generation
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- SSE Wind Turbine FRT Settings (Existing)
- Example of FRT shutdown on SSE Site
- Clustering of Windfarms in GB and possible FRT risk for multiple windfarms

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South Australia Blackout Event - Context

- **Forecast severe weather with increased lightning risk and wind speeds of 120 km/h. Potential for high wind shutdown noted leading to increased monitoring of wind output**
- **System operated to N-1 standard.**
- **Of 1895 MW demand, 883 MW was wind (46%), 330 MW was gas (17%) and, prior to the blackout, 613 MW (32%) was being imported over two interconnectors:**
  - **114 MW on Murraylink DC connector (which did not subsequently trip)**
  - **~500 MW on Heywood AC interconnector (*understood to have a nominal capacity 460 MW* and thermal 15min limit of 750MVA)**

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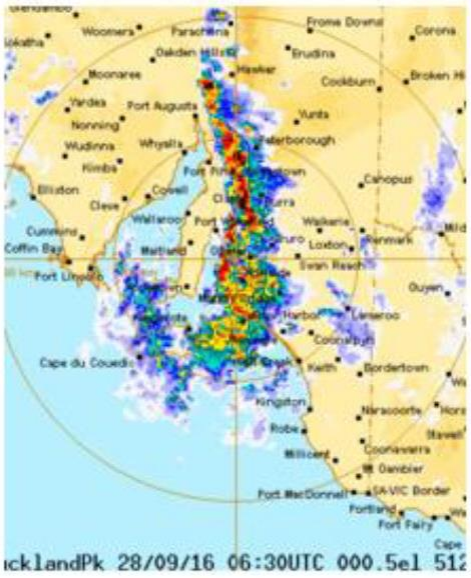
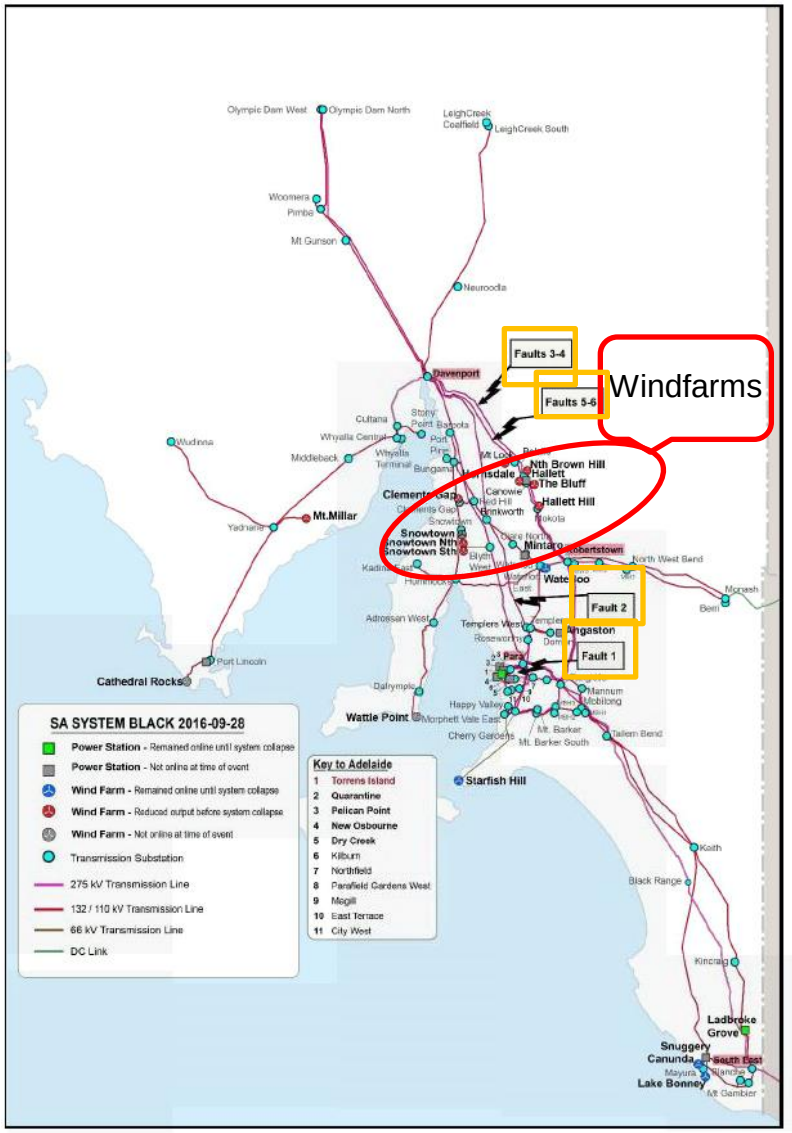
South Australia Blackout Event - Storm Passage and FRT Events

- Five system faults **within 88s** resulted in **<u>six</u>** voltage disturbances and a loss of **445 MW** wind generation. The subsequent increase in load on Heywood interconnector resulted in an interconnector trip leading to a 900 MW sudden loss

South Australia
rain radar 12 minutes after system black





South Australia Blackout – Loss of Wind Generation

Rode through faults

Limit of **9** FRT events (maximum of only 5 events seen)

Did not ride through faults

Limit of only **2** FRT events (6 events seen)

Table 4 SA wind farm responses to six voltage disturbances between 16:17:33 and 16:18:15 on 28 September 2016

Wind farm	Pre-set limit to ride-through events in 120 seconds	Number of times wind turbines activated ride-through mode	Last state of wind turbines prior to system voltage collapse	Output pre-event at 16:18:07 [MW]	Output just prior to separation at 16:18:15.4 [MW]
Canunda	9	1	Operational	27.7	27.2
Lake Bonney 1	5-9	0	Operational	77.7	76.5
Lake Bonney 2,3	9	0	Operational	171.9	158.7
Waterloo	9	5	Operational	96.6	72.9
				Expected MW Reduction	38.6
Clements Gap	2	3	Disconnected	14.5	-0.5
Hallett	2	3	Most turbines disconnected	34.5*	1.7*
Hallett Hill	2	3	Most turbines disconnected	41.3*	19.5*
Mt Millar	Not known	5	Stopped Operation	67.0**	2.8**
North Brown Hill	2	3	Most turbines disconnected	85.5	11.0
Hornsdale	5	6	Stopped Operation	83.9	-1.1
Snowtown North	5	6	Stopped Operation	65.5	-0.8
Snowtown South	5	6	Stopped Operation	42.1	-1.2
The Bluff	2	3	Most turbines disconnected	41.9	-0.3
				Unexpected MW Reduction	445.1
Total MW output				850.1	366.4
Total MW Loss					483.7

* Output not directly recorded. Estimated from other data.
** Value shown is MVA. Real power output (MW) would be somewhat less.

South Australia Blackout - Subsequent Changes to FRT Settings

Table 9 Protection settings implemented in SA wind turbines at the time of incident, and proposed mitigation measures

Wind turbine group	Installed capacity in SA (MW)	Able to ride-through multiple faults on 28 September 2016	Multiple ride-through capability on 28 September 2016	Actions taken for improved ride-through capability
Group A	507	No	2 within 2 minutes[a]	Proposed 4 within 2 minutes
Group B	372	No	5 within 30 minutes (also 5 within 2 minutes)	Changed to 20 within 120 minutes (also 20 within 2 minutes)
Group C	70	No	Varies depending on fault duration, dip size and rate of active and reactive power recovery following fault clearance Can ride through at least 9 faults within 30 minutes if cleared within primary protection clearance time.	Investigating the possibility of modifying fault ride-through mode from zero power mode to reactive power and voltage control mode to avoid sustained power reduction during faults
Group D	627	Yes	Up to 10 within 30 minutes • 10 for Canunda, Cathedral Rocks, Lake Bonney 2, 3 and Waterloo wind farms. • Wattle point, Lake Bonney 1, and Starfish Hill wind farms are yet to be confirmed.	No further increase has been proposed

a In this table, a setting allowing plant to ride through two successive faults but disconnect on the third fault is described as "2 within 2 minutes".

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SSE Generation – Wind FRT Protection Settings

- Informal survey of FRT ride through event capability
- Two main wind technology types; DFIG and 'Fully' rated Converter
- FRT event causes heating in IGBT components of converter
- Limit on no. events / defined period to prevent damage. Wide variation between manufacturers:

Survey of Wind Turbine Manufacturer Settings within SSE

Manufacturer	MW Installed / In Construction (in GB)	Approximate MW Installed in GB (Non-SSE)	Wind Turbine Type	FRT Protection setting (No. of FRT events permitted)
A	784.6	6000	Full Converter	6 events / 30 min period
B	94	< 500	DFIG	None
C	216	1400	DFIG	2 (but possibly more as it depends on depth and length of fault)
D	191	1000	Full Converter / DFIG Mixture	10 (for both DFIG and Convertor)

Note – Manufacturer 'type' above (e.g A, B etc) does **not** relate to the letter groups given in the table on previous slide

- Lack of consistency between manufacturers…but no Grid Code Requirement??

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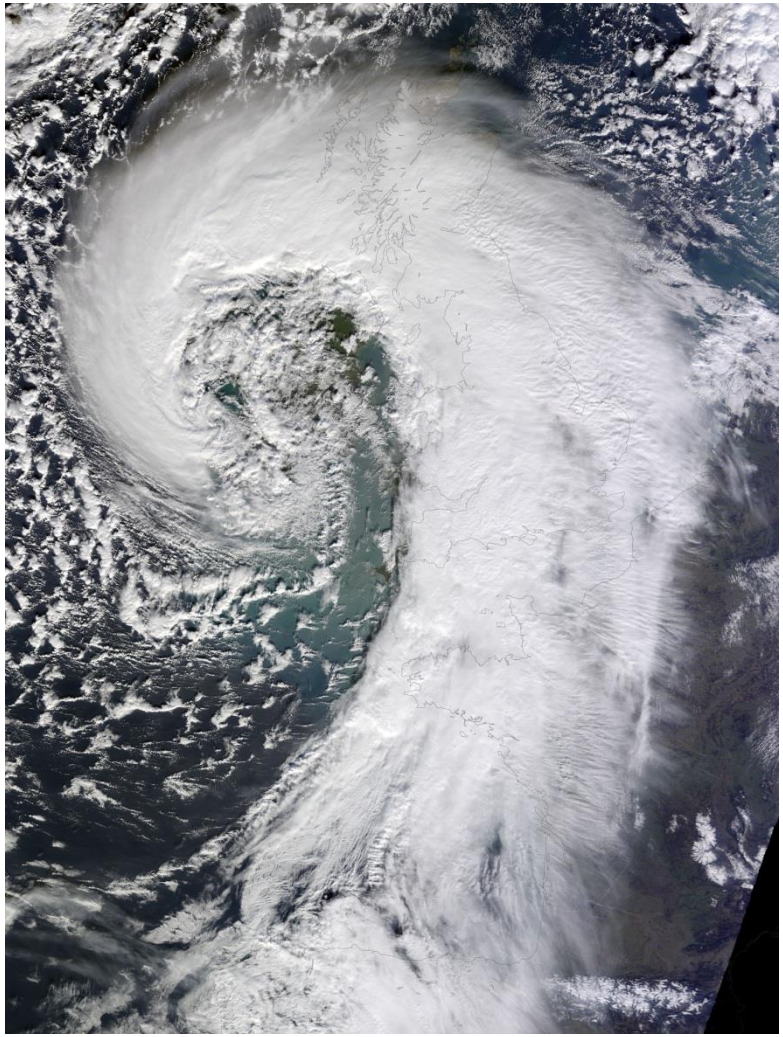
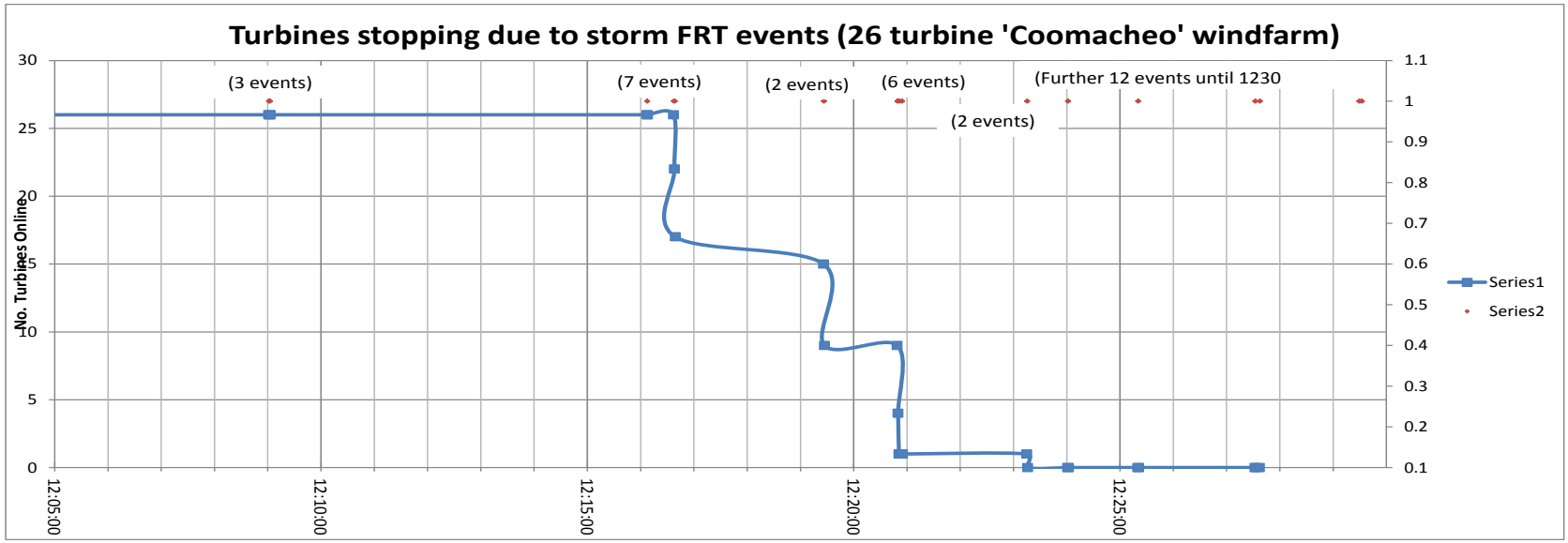
Example of Repeated FRT Event

- Ireland, 2nd February 2014 storm
- Maximum gust: 99 mph at Shannon Airport
- Storms with similar severity previously occurred on 26th December 1998 and 24th December 1997
- Widespread damage to transmission system; 260,000 customers left without power



Example of FRT induced Stop on SSE Windfarm

- Coomacheo Windfarm, 26 x 2.3 MW turbines, SW Ireland



- 33 FRT Events detected by wind turbines within period of ~ 25 min
- Events were clustered *so* ***that several occurred within 1s but were still recorded by the wind turbines as separate events***
- All turbines were stopped *within 5 minutes* of first FRT event

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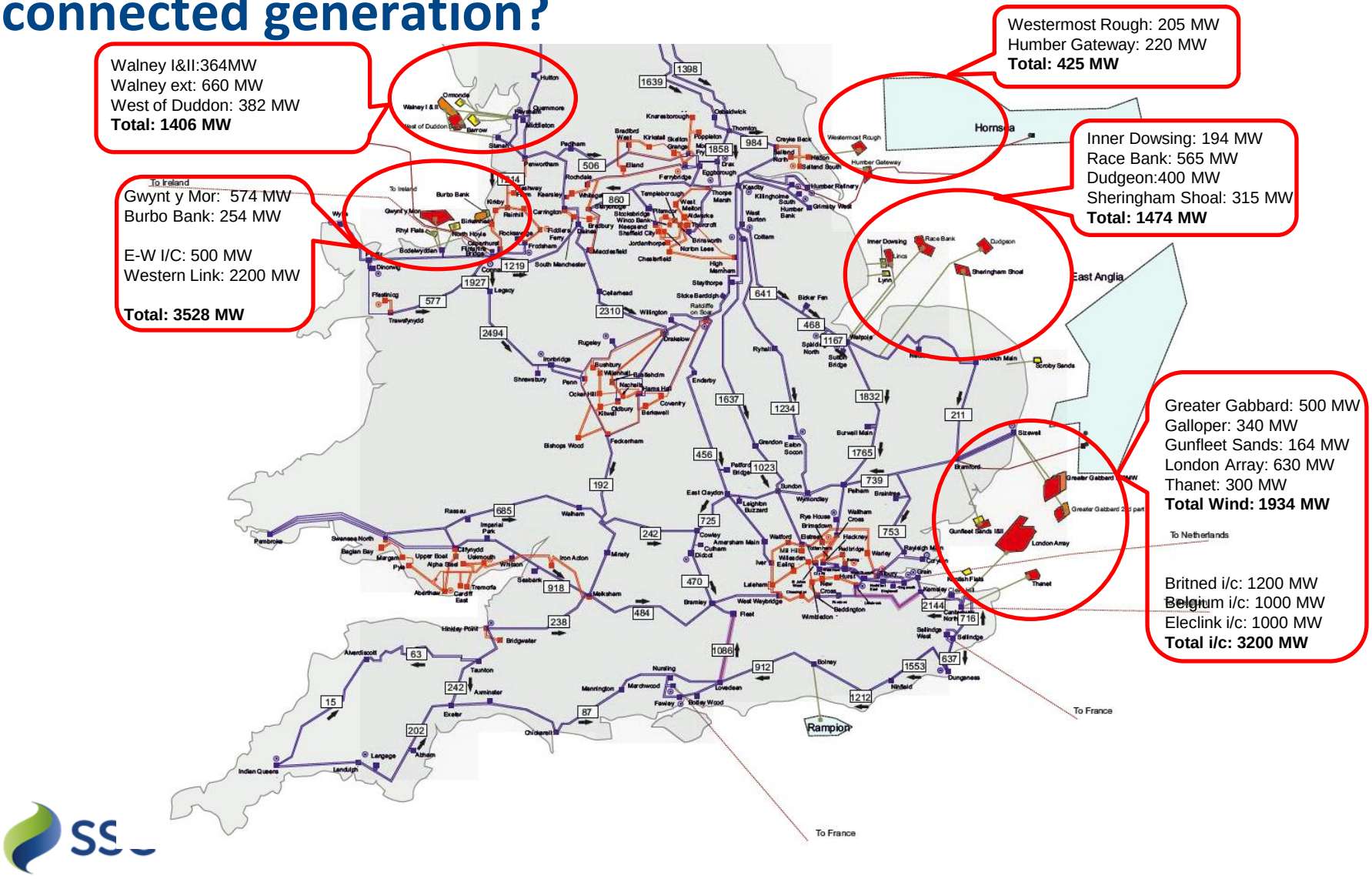
Is there a risk from regional clustering of converter connected generation?



Questions to consider

- Should all transmission wind turbines have a *minimum number of FRT events within defined period*?
- What settings are required for GB?
- Are retrospective updates required?
- Are certain parts of the country at substantially higher risk?
- Are changes needed to existing fast reserve contingency when there is a high potential for FRT risk periods?
- Is there a concurrence of FRT risk with high wind shutdown?
- Are interconnectors with voltage source technology at similar risk?
- Is a workgroup required to consider the above?

Thank you