Grid Code Frequency Response Working Group
Stewart Whyte – System Development

Synthetic Inertia

13th January 2011

Presentation Outline

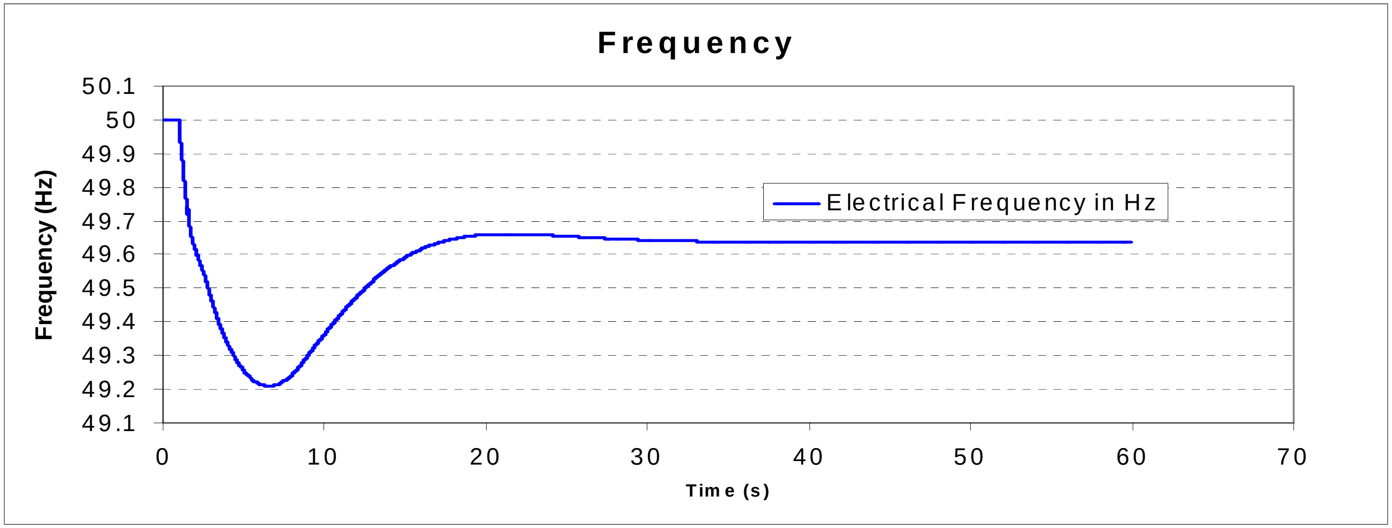
- Summary of results on delay
- Synthetic Inertia ramp amendment
- Future system scenarios
  - Overview of scenarios
  - Response characteristic
  - Synthetic inertia requirement
- National Grid views on Synthetic inertia
  - One shot vs df/dt
  - Power Recovery
  - Power extraction

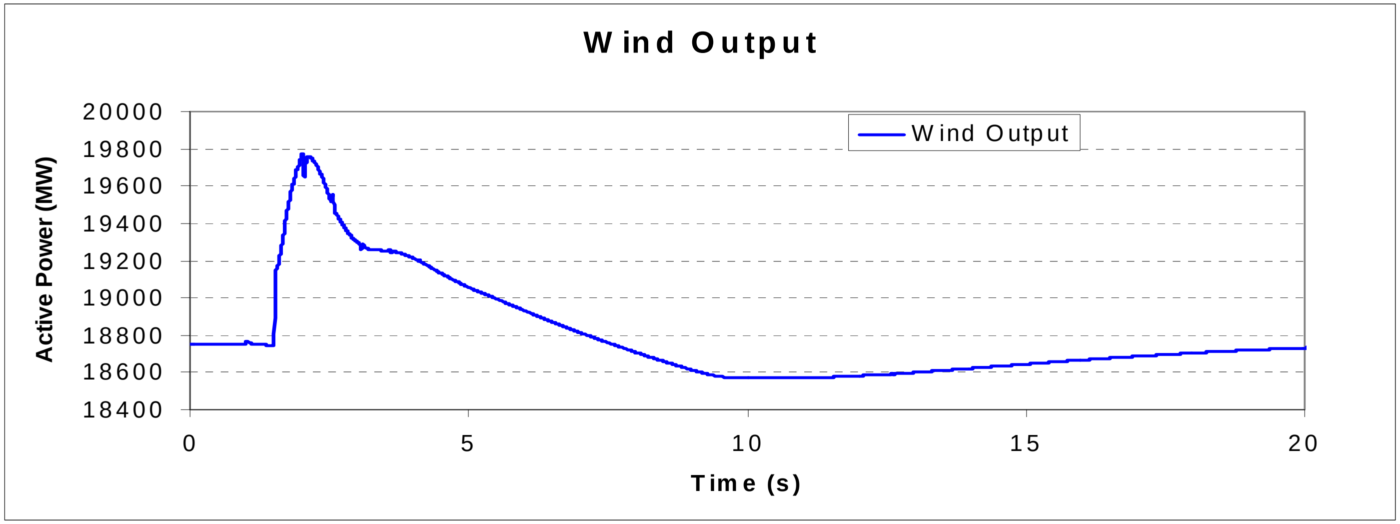
Summary of delay results

- At the last FR tech sub group meeting National Grid presented that a delay of a short time could be tolerated.
- National Grid looked at delay but did not reduce the speed of the inertial response
- Some of the group thought this would be useful
  - delays have now been studied for certain systems

75% wind on 25GW system

- 0.5s delay and 0.5s ramp

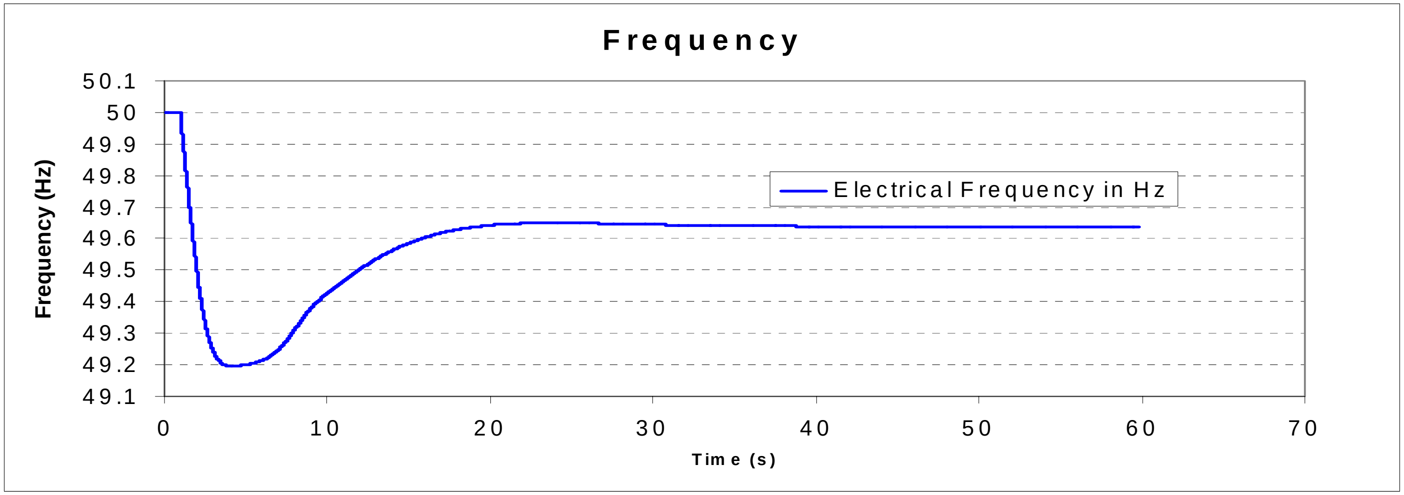


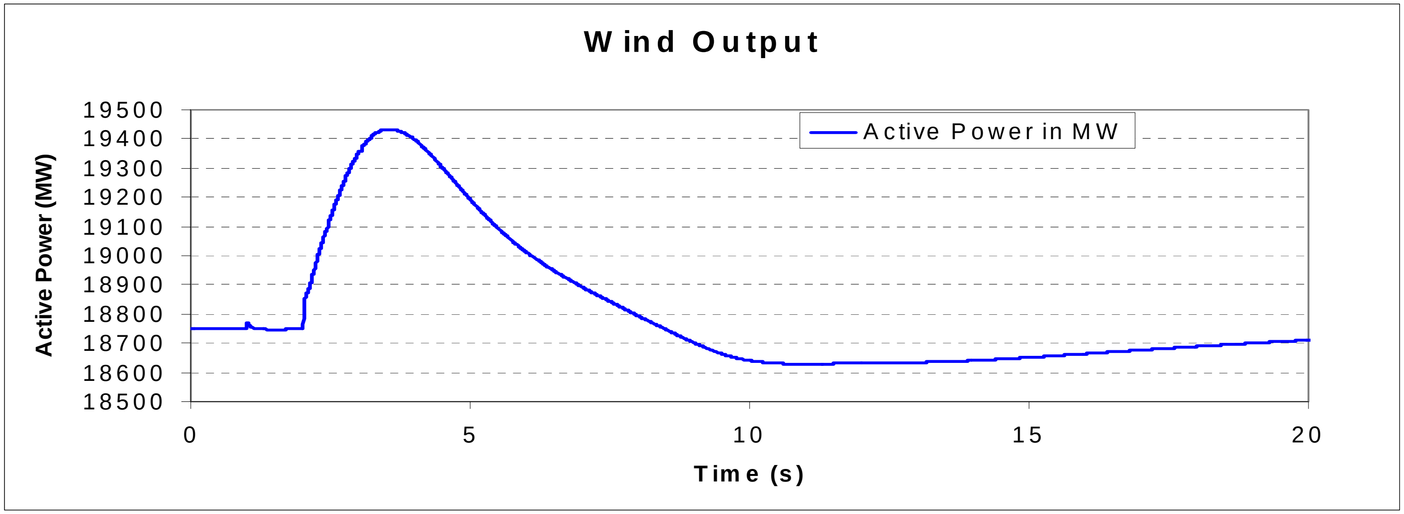


75% wind on 25GW system

nationalgrid
THE POWER OF ACTION

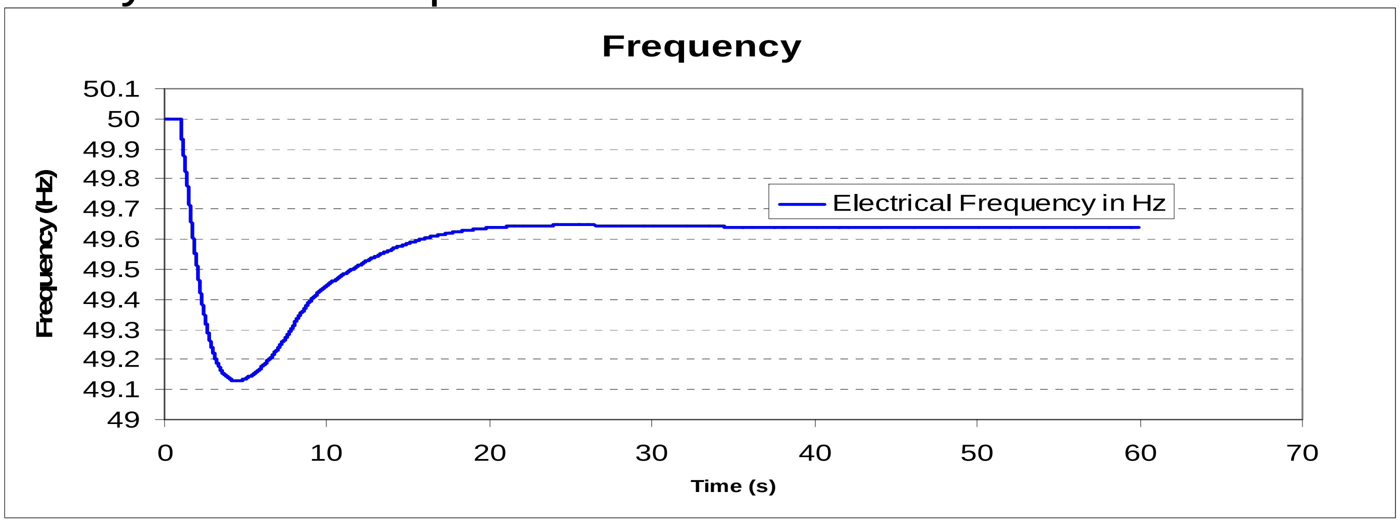
- 1s delay and 2s ramp

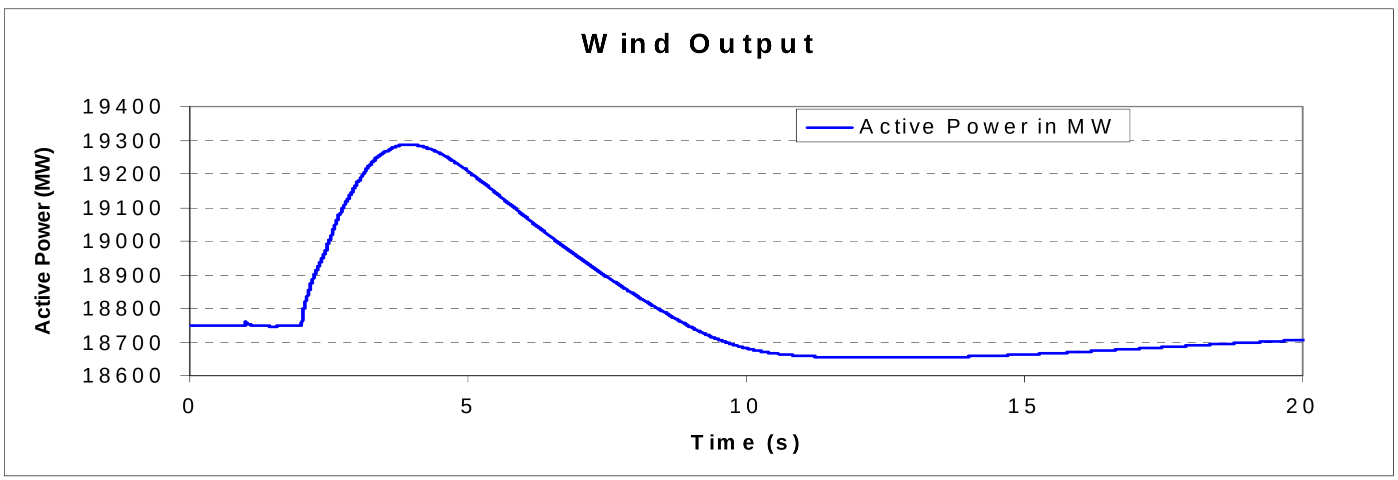




75% wind on 25GW system

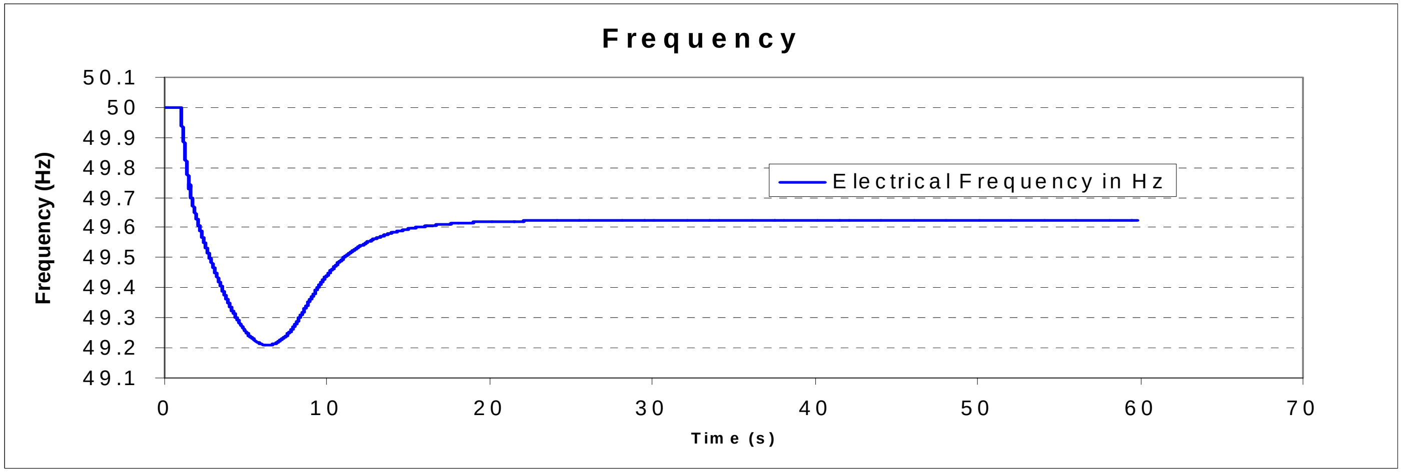
- 1s delay and 3s ramp

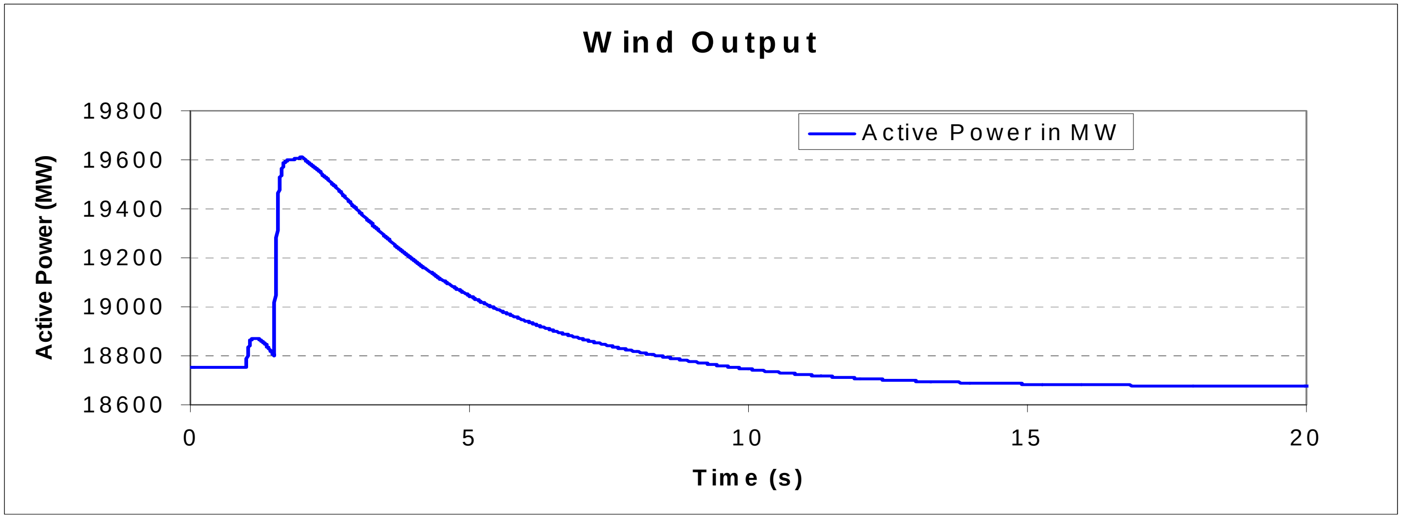




75% wind on 25GW system, one shot

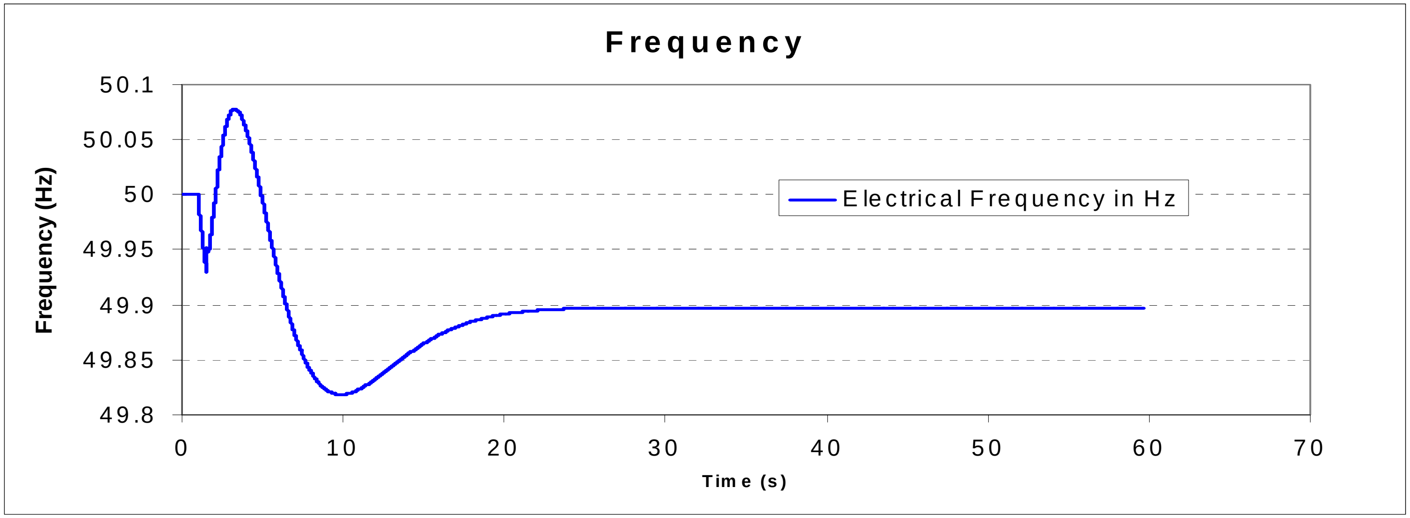
- 0.5s delay and 0.5s ramp

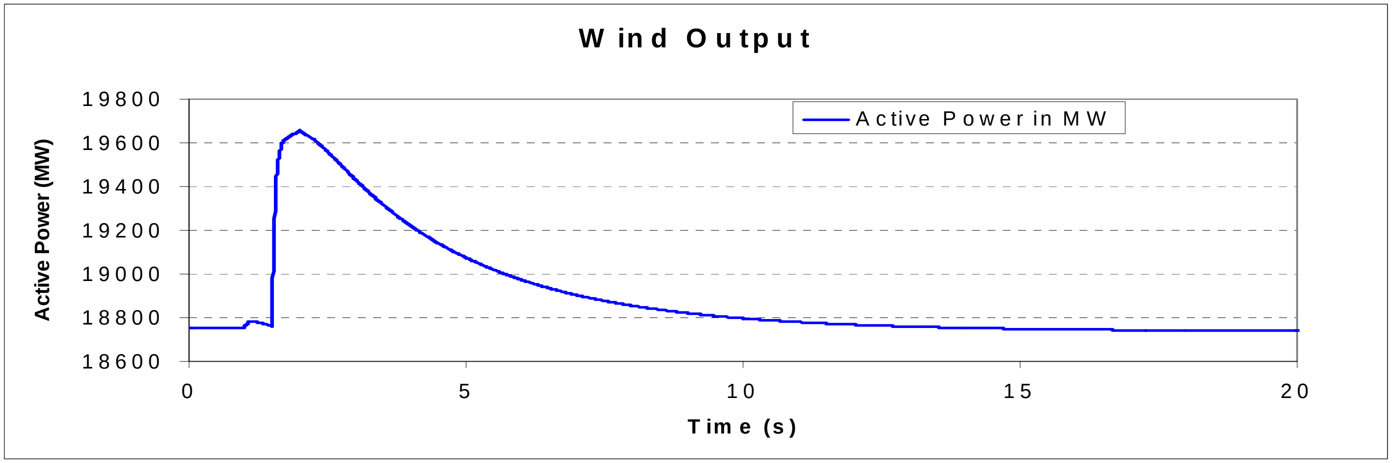




75% wind on 25GW system, one shot lower loss 500MW

- 0.5s delay and 0.5s ramp





SI key questions

- What can be achieved?
- How fast can it be achieved?
- Recovery period
  - At what wind speeds is the recovery period worst
  - How can it be minimised
- Cost

SI issues

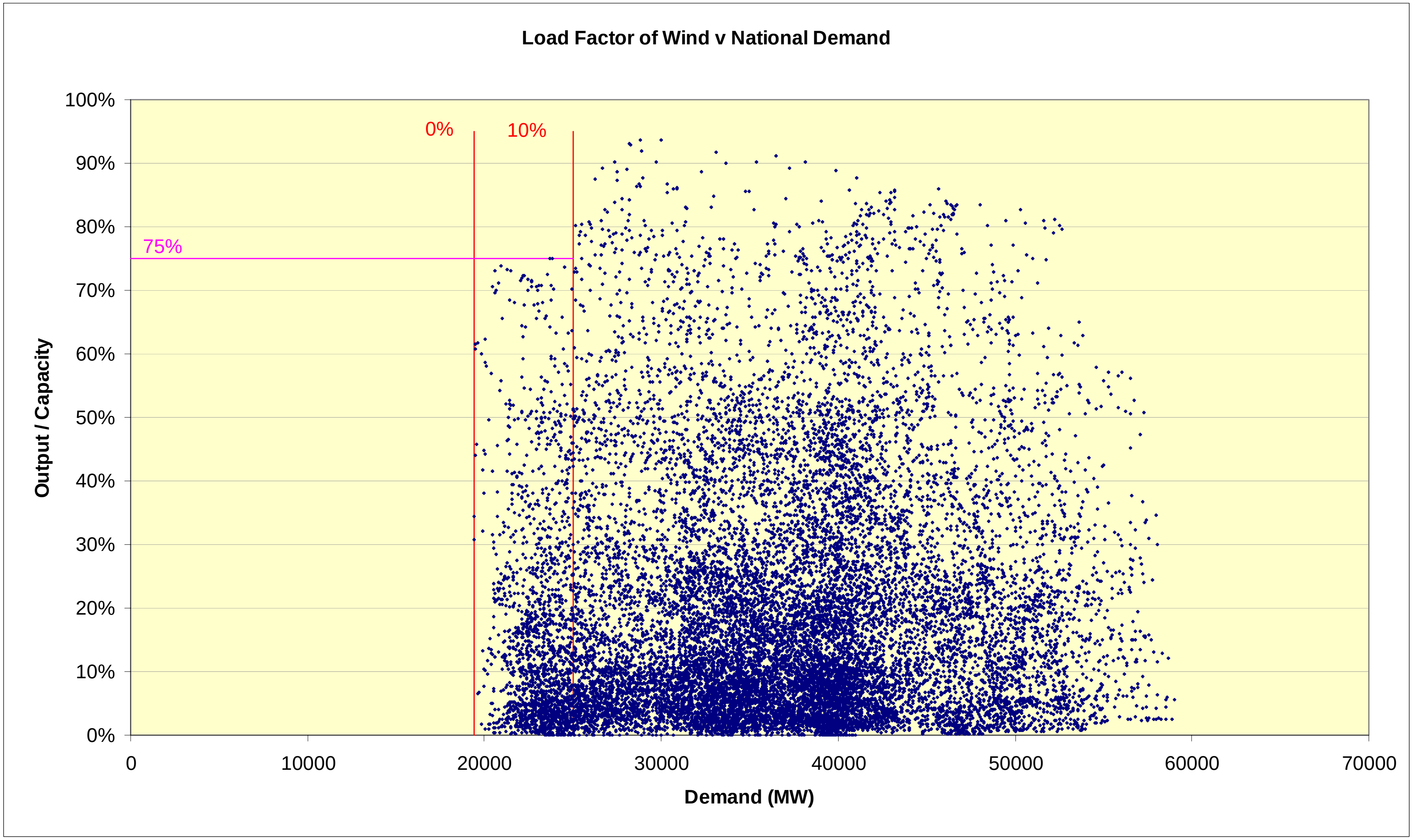
- df/dt deadband
- Appropriateness of df/dt control
- National Grid models used
- Control scheme interactions
  - FRT and SI
  - Frequency Response and SI
  - Reactive and SI
- Recovery period
- Filtering of df/dt
- ROCOF

Df/dt vs One Shot

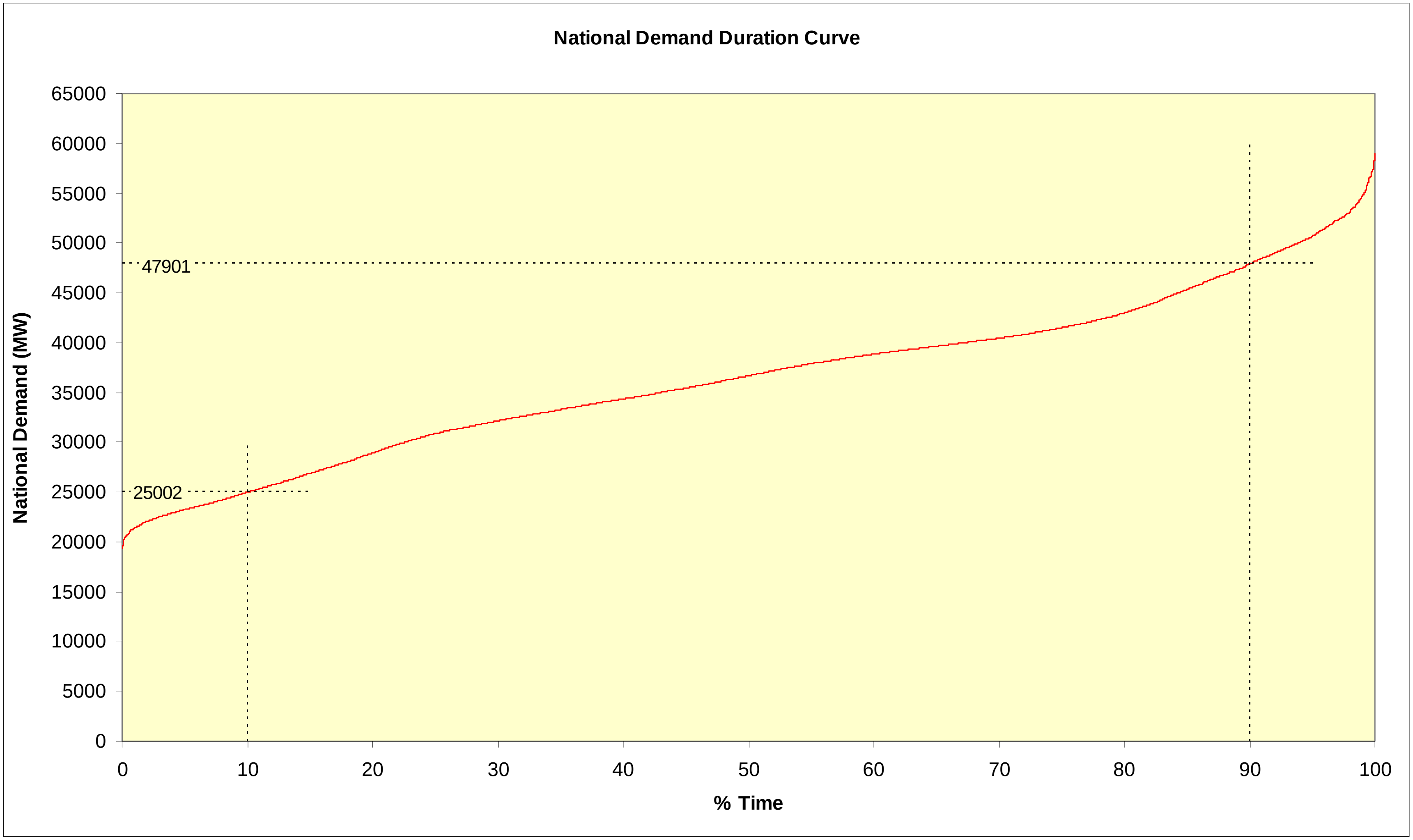
- Appropriateness of df/dt has been questioned from the outset
- Df/dt would be excellent for augmenting power in proportion to the incident compared to the one shot
- Major disadvantage of df/dt is the measurement of the signal
  - Trigger
  - Further augmentation of power
- What else could be done with df/dt to make it more appropriate
  - More time to measure for a trigger
  - Trigger on df/dt and Δf
  - Greater filtering of signal required

Power Recovery

- Manufacturer liaison has identified an issue with the recovery period
- Recovery period characteristics
  - Wind speed dependant
  - Under worst case can be as deep as 25% of MW output resulting a double dip
  - Recovery can last for as long as 40s
  - Recovery at lower wind speeds is manageable – examples provided in previous meetings
  - There is no recovery period when operation is at or beyond rated wind speed
- Reduce the upfront power extraction
- Manufacturer meetings have led National Grid to believe that the return to optimal rotational speed can be controlled



Load Factor of Wind v National Demand
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Output / Capacity
0%
10%
75%
0
10000
20000
30000
40000
50000
60000
70000
Demand (MW)


National Demand Duration Curve
National Demand (MW)
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
47901
25002
0
10
20
30
40
50
60
70
80
90
100
% Time

Generation Mix - Future Scenario for Response and Inertia

	GG Year:2020 Generation Capacities	Low Demand 25GW		Median Demand 35GW		High Demand 45GW		GG Year: 2025 Generation Capacities	Low Demand 25GW		Median Demand 35GW		High Demand 45GW		
Demand		25	25	35	35	45	45		25	25	35	35	45	45	
Additional Demand (ie Pumping)		2	2						2	2					
Total Demand		27	27	35	35	45	45		27	27	35	35	45	45	
Generation															
"Must Run" generation															
Nuclear	*11.2*	6.7	6.7	7.9	7.9	9.6	9.6	*9.4*	5.6	5.6	6.6	6.6	8.0	8.0	GG Generation Capacities
Wind	*26.8*	20.1	.0	21.4	1.3	24.1	1.3	*38.1*	28.6	.0	30.5	1.9	34.3	1.9	as Scaled by factors
Other	*4.5*	*2.9*	*2.9*	*3.4*	*3.4*	*4.1*	*4.1*	*12.9*	*2.5*	*2.5*	*7.4*	*7.4*	*12.6*	*12.6*	
Total "Must Run"	*42.5*	29.8	9.7	32.7	12.6	37.7	15.0	*60.4*	36.7	8.1	44.5	15.9	54.9	22.4	
Total Generation Capacity	*100.0*							*111.8*							
Primary Response															
Requirement		2.0	2.0	1.7	1.7	1.4	1.4		2.0	2.0	1.7	1.7	1.4	1.4	Total assumed requirement
Static Response		0.2	0.2	0.2	0.2	0.2	0.2		0.2	0.2	0.2	0.2	0.2	0.2	LF Triggered response
Net Response Req		1.8	1.8	1.5	1.5	1.2	1.2		1.8	1.8	1.5	1.5	1.2	1.2	Response required from generation
Response on Synchronous Plant		0.21	1.80	0.51	1.50	0.68	1.20		0.00	1.80	0.00	1.50	0.00	1.20	
Response on Asynchronous Plant		1.59	0.00	0.99	0.00	0.53	0.00		1.80	0.00	1.50	0.00	1.20	0.00	
Response on Synchronous Plant															
Assumed Loading Point		65%	65%	75%	65%	85%	85%		65%	65%	75%	85%	85%	85%	
Assumed Deload/Response Ratio		36%	36%	50%	36%	55%	55%		36%	36%	50%	55%	55%	55%	Response provided for a given deload
Responsive Plant Deload		0.6	5.0	1.0	4.2	1.2	2.2		0.0	5.0	0.0	2.7	0.0	2.2	
Power Output on Responsive Plant		1.7	14.4	4.1	12.0	8.2	14.6		0.0	14.4	0.0	18.3	0.0	14.6	
Estimated number of machines (modules @800MW)		3	25	7	21	12	22		0	25	0	27	0	22	Drives response ramp rate assumption
Response on Asynchronous Plant															
Assumed Loading Point		65%	100%	85%	100%	85%	100%		65%	100%	75%	100%	85%	100%	
Assumed Deload/Response Ratio		36%	0%	55%	0%	55%	0%		36%	0%	50%	0%	55%	0%	Response provided for a given deload
Responsive Plant Deload		4.5	0.0	1.8	0.0	1.0	0.0		5.0	0.0	3.0	0.0	2.2	0.0	
Power Output on Responsive Plant		12.7	0.0	12.1	0.0	6.4	0.0		14.4	0.0	12.0	0.0	14.6	0.0	
Estimated number of machines		2862	0	2315	0	1228	0		3240	0	2500	0	2805	0	Drives response ramp rate assumption
Additional Balancing (Pullback)		0.0	0.0	0.0	0.0	0.0	0.0		4.7	0.0	6.5	0.0	7.7	0.0	Pullback assumed on Wind
Power Output on Non-responsive Plant		2.9	0.0	7.5	0.0	16.7	0.0		4.5	0.0	9.0	0.0	9.8	0.0	Used to derive SI capable plant (for scenarios where concurrent response and SI is not feasible)
Aggregate Response															
Power Output on Responsive Plant		14.4	14.4	16.2	12.0	14.6	14.6		14.4	14.4	12.0	18.3	14.6	14.6	
Responsive Plant Deload		5.0	5.0	2.8	4.2	2.2	2.2		5.0	5.0	3.0	2.7	2.2	2.2	
Additional Output Reqd		1.7	22.4	4.1	26.6	8.3	32.2		0.0	23.9	0.0	21.8	0.0	24.8	
Power on Synchronous Machines															
H = 4		6.7	6.7	8.2	8.2	10.1	10.1		5.6	5.6	11.3	11.3	17.5	17.5	
H = 6		4.6	20.3	7.2	25.5	11.7	33.5		2.5	21.4	2.7	21.8	3.0	25.6	
		11.4	27.0	15.4	33.7	21.9	43.7		8.1	27.0	14.0	33.1	20.5	43.1	
Capacity on Synchronous Machines (based on 0.85pf capability)															
H = 4		10.3	10.3	9.3	9.3	11.2	11.2		9.0	9.0	7.7	7.7	9.4	9.4	Used to drive 'natural' inertia assumption
H = 6 (non-responsive)		3.4	3.4	3.7	3.7	4.1	4.1		2.9	2.9	3.1	3.1	3.5	3.5	
H = 6 (deloaded for response)		2.7	22.9	6.0	19.1	11.1	19.8		0.0	22.9	0.0	24.7	0.0	19.8	
Power on Asynchronous Machines		15.6	0.0	19.6	1.3	23.1	1.3		18.9	0.0	21.0	1.9	24.4	1.9	
Pre-2013 Asynchronous Capacity (no SI)	7.4	5.5	0.0	5.9	0.4	6.6	0.4		5.5	0.0	5.9	0.4	6.6	0.4	Generation Completed before 2013
Power on SI Capable Asynchronous Generation		10.1	0.0	13.7	1.0	16.5	1.0		13.3	0.0	15.1	1.5	17.8	1.5	
Max Power on Non-Responsive SI Capable Asynchronous Generation		2.9	0.0	7.5	1.0	16.5	1.0		4.5	0.0	9.0	1.5	9.8	1.5	
Max Power Available on Non-Responsive SI Capable Asynchronous Generation		2.9	0.0	7.5	1.0	16.5	1.0		9.2	0.0	15.5	1.5	17.5	1.5	
Total Generation		**27.0**	**27.0**	**35.0**	**35.0**	**45.0**	**45.0**		**27.0**	**27.0**	**35.0**	**35.0**	**45.0**	**45.0**	Check - should balance demand

Plant Running Scaling Factors

	Low Demand 25GW		Median Demand 35GW		High Demand 45GW	
	High Wind	**Low Wind**	**High Wind**	**Low Wind**	**High Wind**	**Low Wind**
Nuclear	60%	60%	70%	70%	85%	85%
Wind	75%	0%	80%	5%	90%	5%
Other	75%	75%	80%	80%	90%	90%

Assumed Response Characteristic

Load Point (pu)	Response (pu)	Response/ Deload
0.55	0.125	28%
0.65	0.125	36%
0.75	0.125	50%
0.85	0.082	55%
1	0	0%

Power Supplied Over Cumulative Hours for the 3 year period July 2007 - Oct 2010