Grid Code Frequency Response Working Group
Antony Johnson – System Technical Performance

Simulated Inertia

10 September 2010

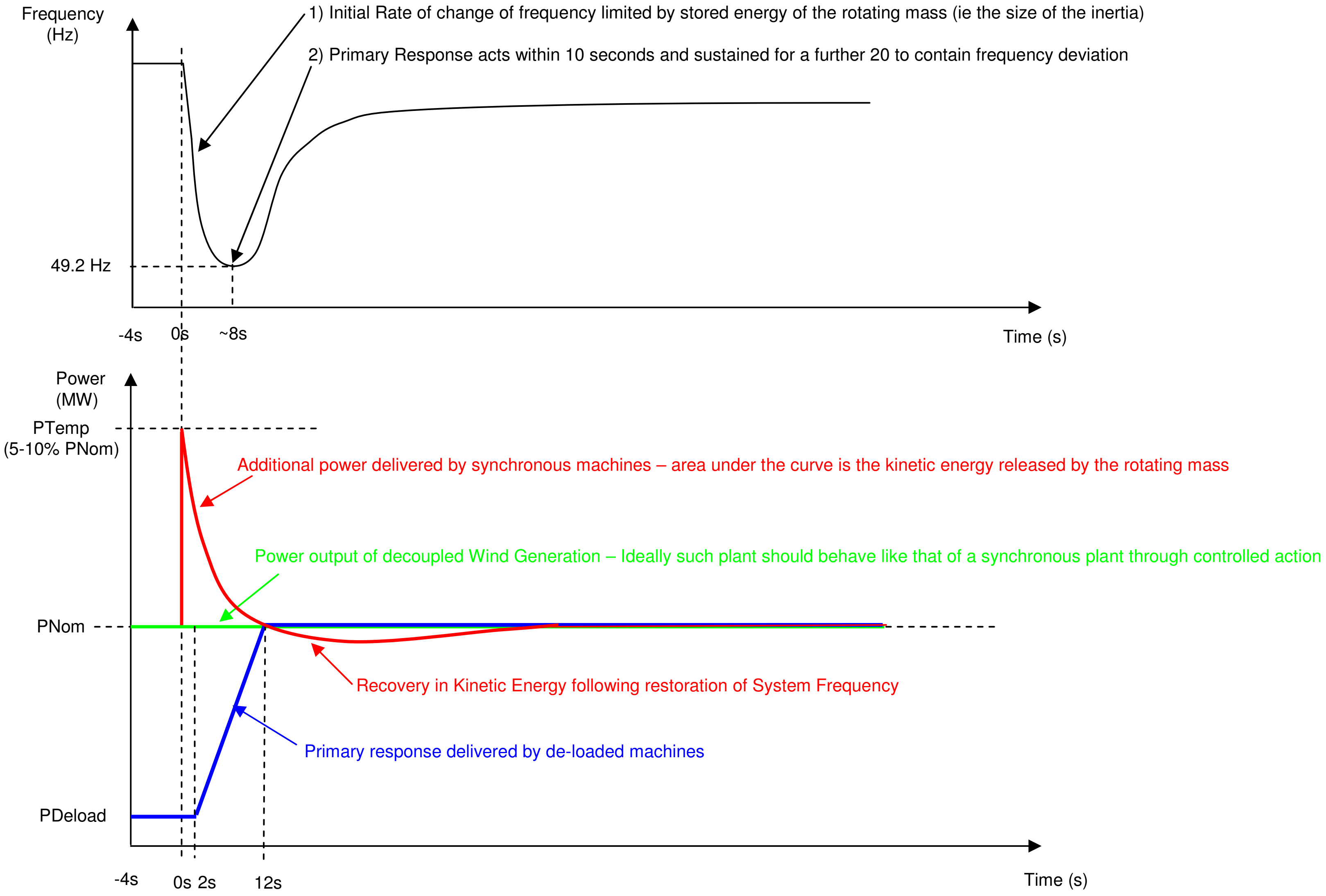
Summary of Work Completed to Date

- The effect of Inertia on the Transmission System (Resume')
- Control Action Proposals
- Issues identified in calculating settings
  - Interaction between Inertia and Primary Response Provisions
  - 1800MW Loss
  - Costs
  - Capability / Delivery
- High level proposals
  - 1320MW loss possible
  - 1800MW more complex?
- Conclusions

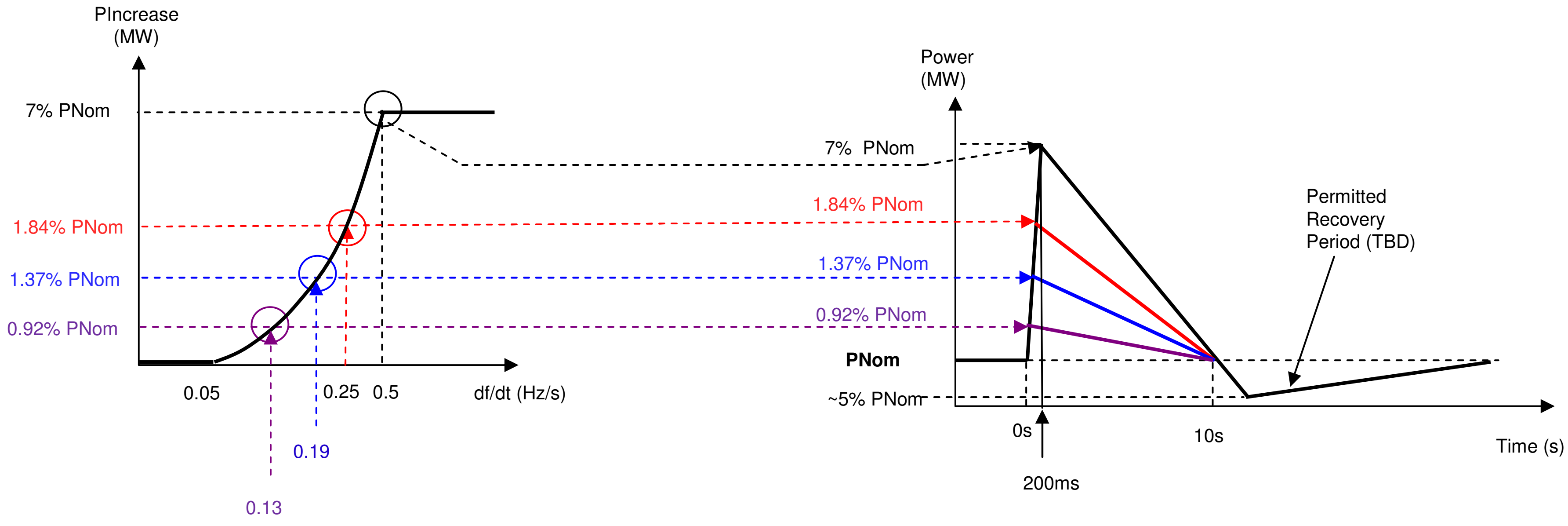
Why Inertia is Important

- Decoupled plant such as wind generation and HVDC Plant is insensitive to changes in system frequency
- By 2020 under a “Gone Green Scenario” there could be 29GW of Wind Generation 2/3 of which being Offshore (ie beyond the minimum demand)
- Renewable Generation share grows from 5% - 36%
- Without the additional contribution of active power into the network from the natural effect of machine Inertia, the implications are:-
    - Rapid increase in rate of change of system frequency
    - Lower minimum system frequencies
    - System Security issues!

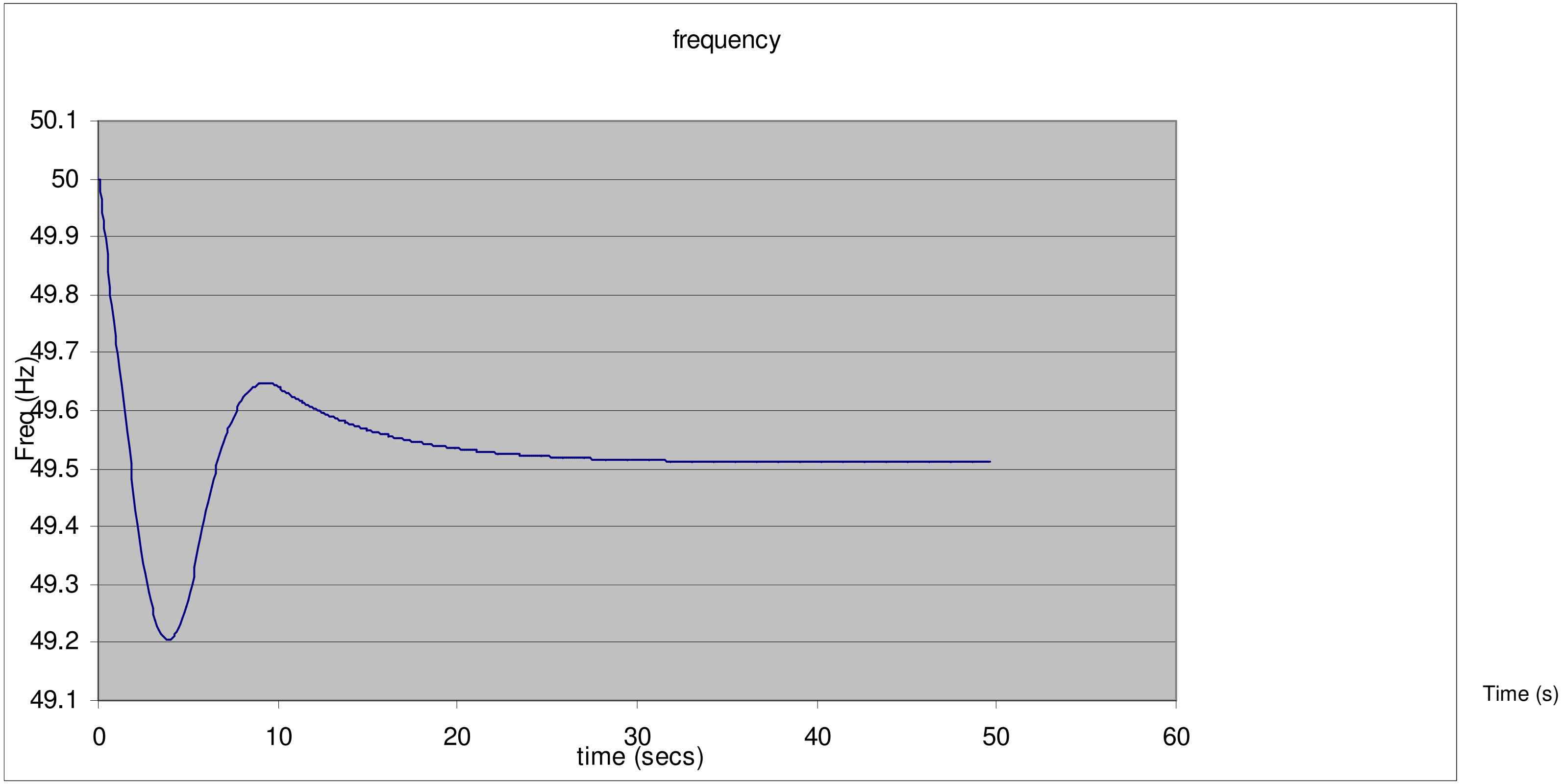
A summary of the Requirement / Issue



Control Scheme 1 – Power Injection based on initial df/dt only – One Shot

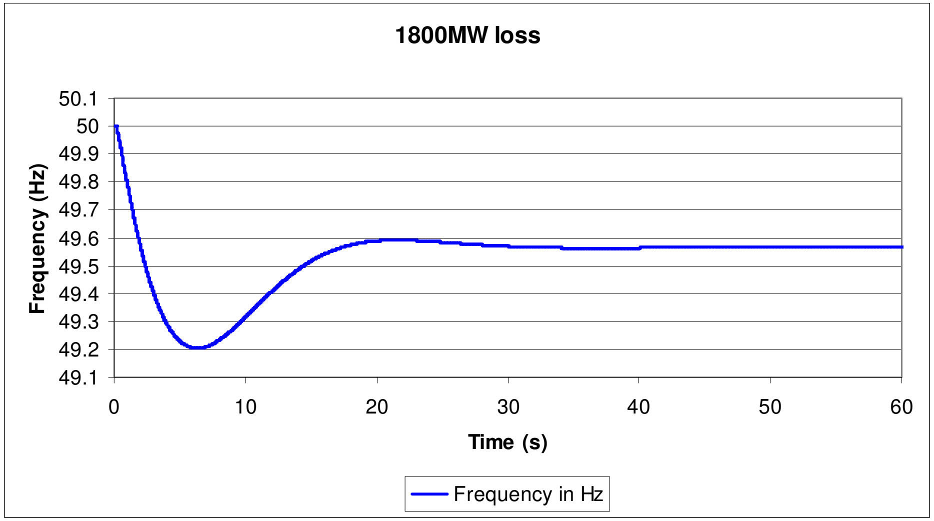


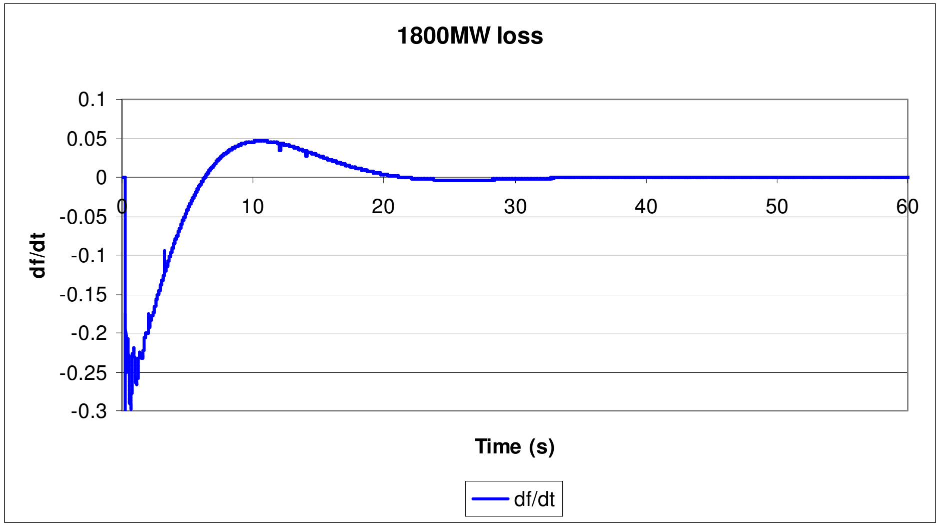
Control Scheme 1 – Power Injection based on initial df/dt only – One Shot



df/dt for an 1800MW loss with 25 GW of Demand

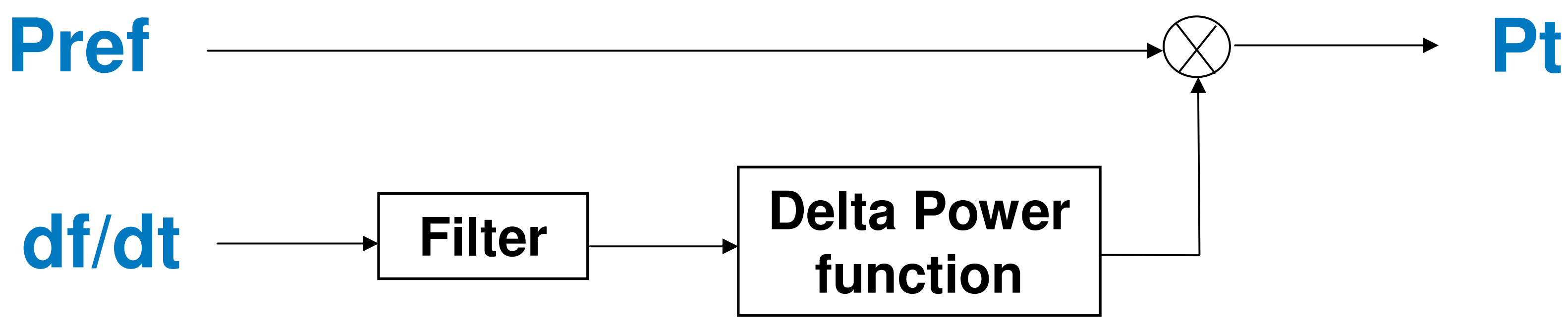
nationalgrid
THE POWER OF ACTION



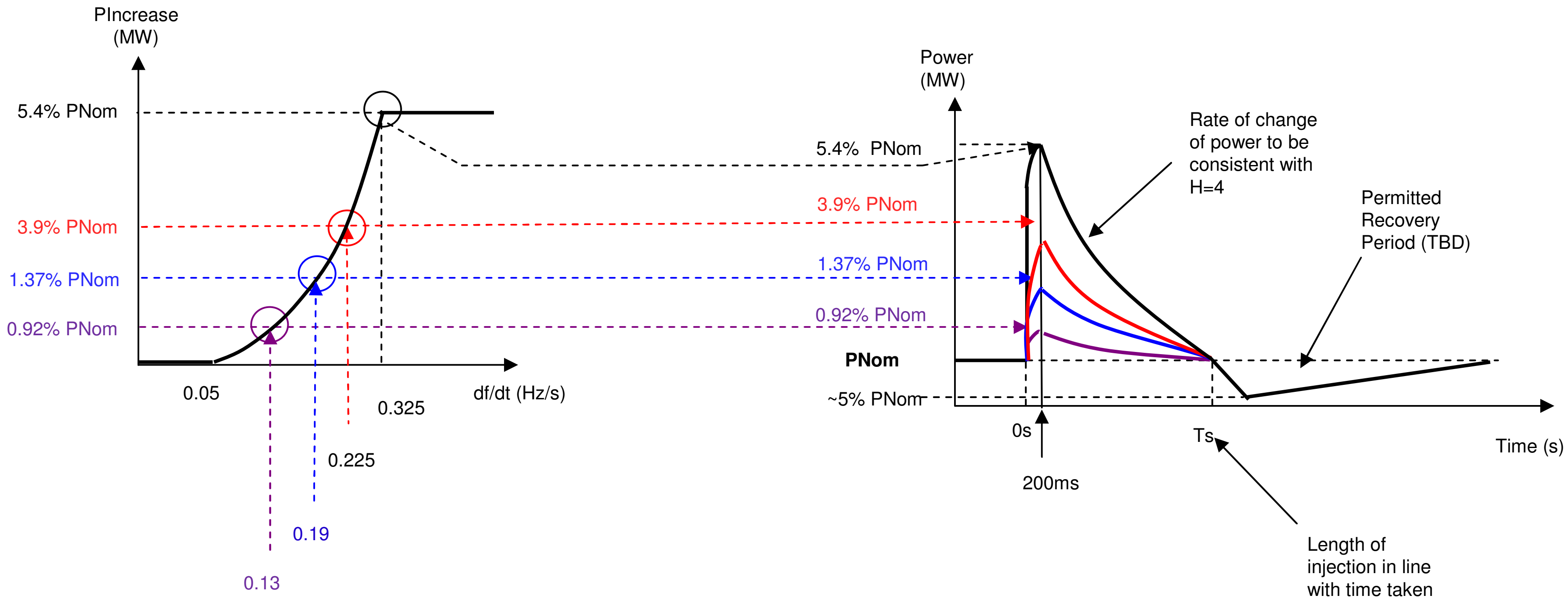


Synthetic Inertia controller used for National Grid modelling

nationalgrid
THE POWER OF ACTION

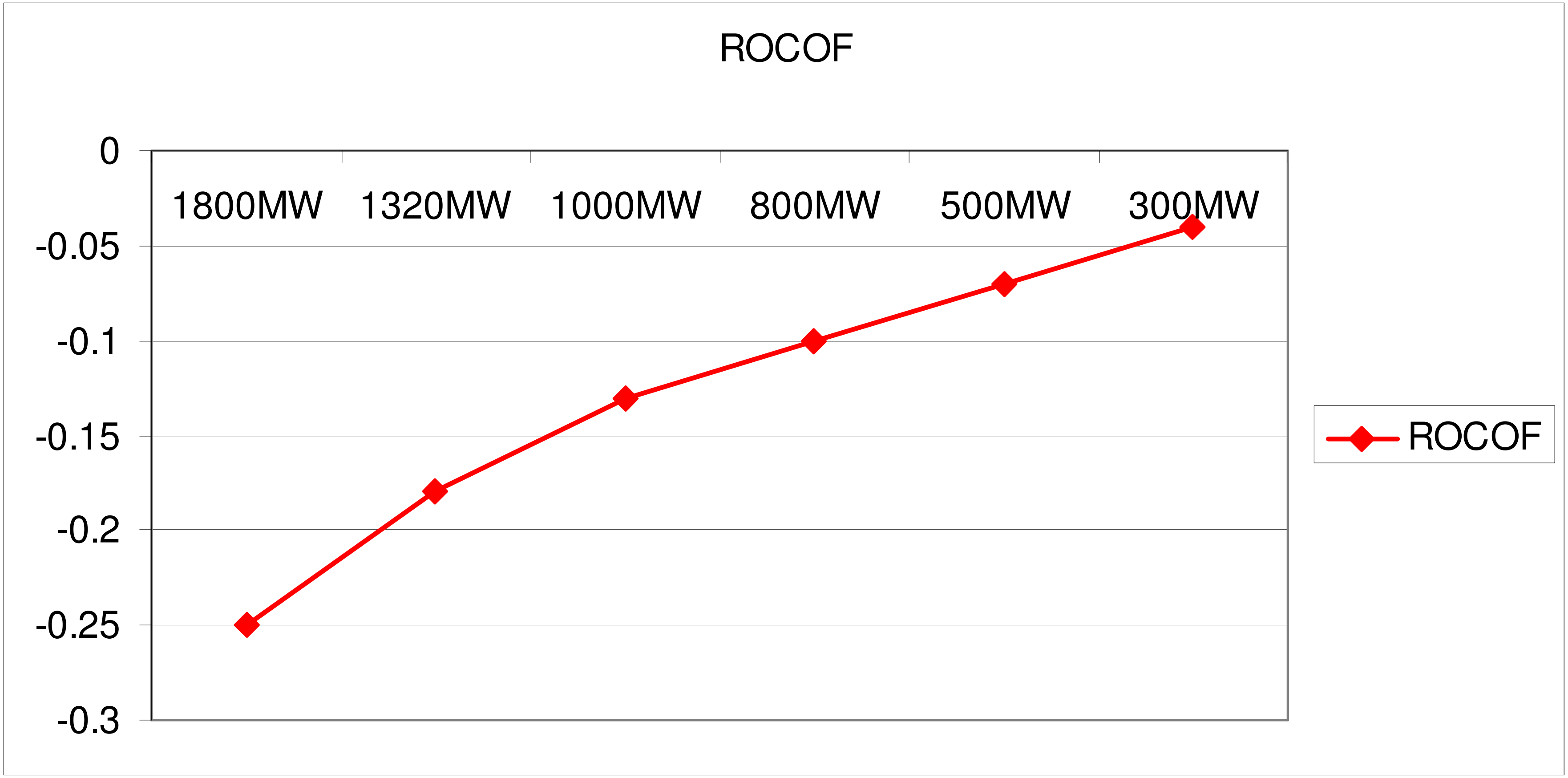


Control Scheme 2 – Power Injection based on full df/dt control pre/ post fault

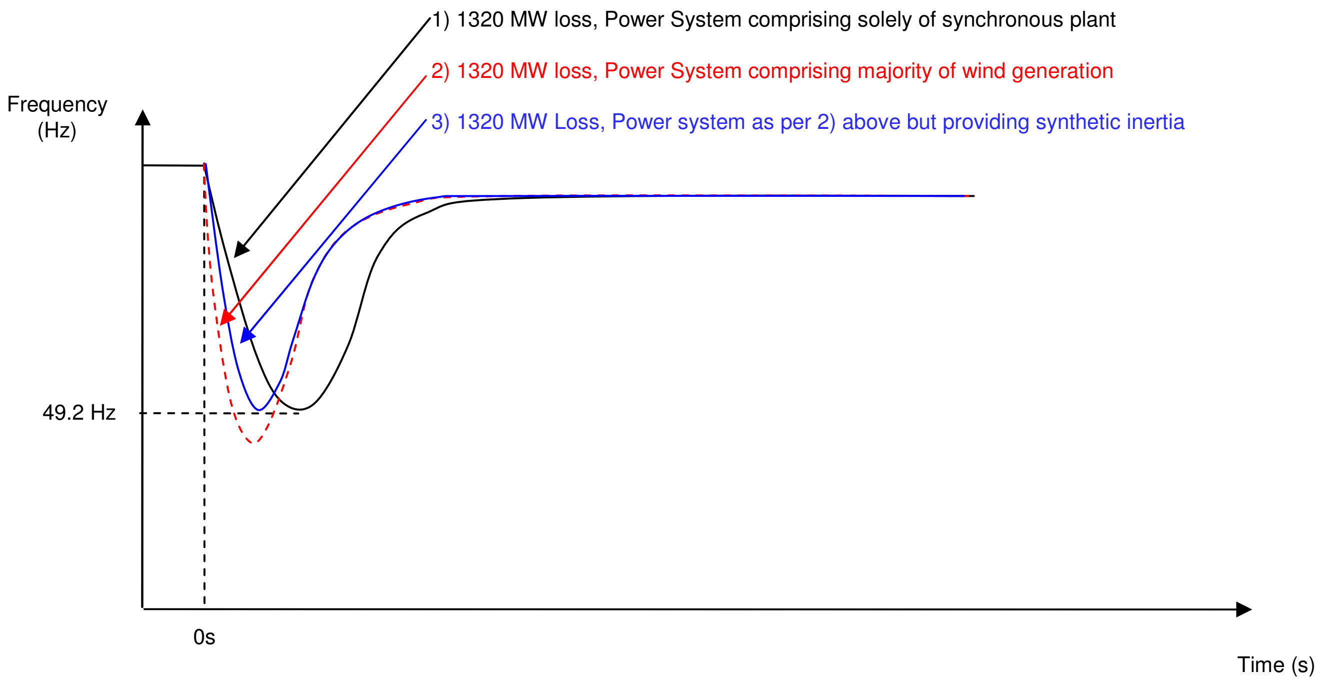


Rate of Change of Frequency – 25 GW Demand – Synchronous Generation Modelled with H = 4MWs/MVA

nationalgrid
THE POWER OF ACTION



Synthetic Inertia – Derivation of Settings



df/dt Power Injection Requirements

nationalgrid
THE POWER OF ACTION

H Eq (MWs/MVA)	Min Frequency (Hz)	Time to MinFreq (Hz)	Loss (MW)	System Demand (GW)	Primary Response (MW) (2 Second Delay fully available in 10s)	ROCOF (Hz/s) over 100ms		Synthetic Inertia % or RC Linear drop over 10s	ROCOF (Hz/s) over 100ms	Min Frequency (Hz)	Time to MinFreq (Hz)	System Demand (GW)
4	49.811	8.8	300	25	260	0.04181		0.7	0.1	49.814	7	24.99
4	49.75	8.8	400	25	350	0.05577		0.92	0.1319	49.75	6.8	24.99
4	49.67	9	500	25.01	410	0.06975		1.12	0.16433	49.67	7.3	25
4	49.615	8.9	600	25	500	0.08376		1.37	0.19427	49.615	7.3	25
4	49.557	8.8	700	25	600	0.09772		1.6	0.22361	49.558	7	25
4	49.482	9.2	800	25	650	0.11183		1.84	0.25377	49.482	7.4	25
4	49.422	8.9	900	25	750	0.12581		2.05	0.28229	49.422	7.3	25
4	49.363	8.8	1000	25	850	0.1398		2.27	0.3099	49.363	7	25
4	49.303	8.5	1100	25	950	0.15378		2.485	0.33692	49.303	6.7	25.01
4	49.2436	8.4	1200	25	1050	0.16776		2.7	0.36341	49.243	6.6	25
4	49.2	8.1	1300	25	1200	0.1815		2.9	0.38714	49.2	6.6	25
					Primary Response (MW) 2 Second Delay fully available in 5.5 seconds			Synthetic Inertia % or RC Linear drop over 8s				
4	49.21	5.4	1800	25	1560	0.25266		4.2	0.5127	49.203	4	25

Synthetic Inertia, 1800MW loss and Primary Response

nationalgrid
THE POWER OF ACTION

- To date high level proposals have been developed for synthetic Inertia.
- As part of this analysis key issues have been identified
- For a System Demand of 25GW and an 1800MW loss, with all synchronous plant (no wind) and an equivalent System H of 6.18Mws/MVA it is not possible to secure the system based solely on dynamic primary response (ie full delivery in 10 seconds).
- To secure the System, slightly higher volumes of primary response are required (eg 1560MW for a 1800MW loss) but it needs to be much faster acting. Based on these studies full delivery in 5.5 seconds!
- On the other extreme 1 nuclear plant, all other non responsive plant being wind with pumped storage providing primary response only synthetic inertia can be made to secure the system for an 1800MW loss. In equivalent terms this would be much larger than that provided by inertia alone from synchronous plant.
- NOTE:- this is a pessimistic case but assumes no frequency response from demand, the Governors are constrained to a Grid Code requirement of 10% in 10 seconds with a 2 second delay.
- The average machine inertia 4MWs/MVA + demand inertia of 2.18MWs/MVA on a 25GW system giving a total of 6.18MWs/MVA. The lowest inertia seen on the system is based on a real event is in the order of 5.4MWs/MVA.

Implications for Synthetic Inertia

nationalgrid
THE POWER OF ACTION

- The Inertial Response contribution needs to match the delivery of Primary Response – minimum requirements?
- Static Response ?
- With a large proportion of wind generation / decoupled plant, the initial rate of change of System Frequency is much greater
- Should decoupled plant provide an inertial response capability greater than the natural capability of a system comprising solely of Synchronous Plant with a minimum inertia?
- Power Recovery from wind generation operating below rated wind speed?
- Costs / Cost Recovery / Commercial Issues
- National Grid Proposal – To develop an Inertial Response Capability with initial settings suitable for a 1320MW loss
  - Settings designed to cover an 1320 MW loss
  - Capability / settings to cover an 1800MW loss??
  - *Requires agreement from the Working Group*

High Level Proposals Based on Capability

- Generating Units, Power Park Modules and DC Converters which are decoupled from the mechanical prime mover and which do not contribute to System Inertia will be required to satisfy the requirements.
- The initial Active Power Injected should be in proportion to the rate of change of System Frequency (ie the additional power supplied needs to be in proportion to the size of the generation loss to avoid over frequencies).
- The initial rise in Active Power should be fully delivered to the Transmission System within 200ms.
- After the initial injection in Active Power, the Active Power should decay in proportion to the rate of change of system frequency.
- The maximum step change in power should be no more than ~7% (based on current studies but depends on 1800MW loss / Primary Response delivery) of Pnominal

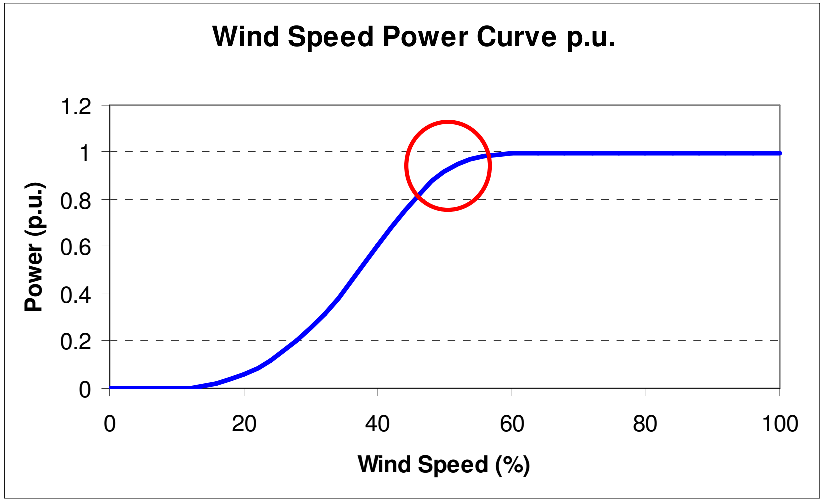
High Level Proposals (2)

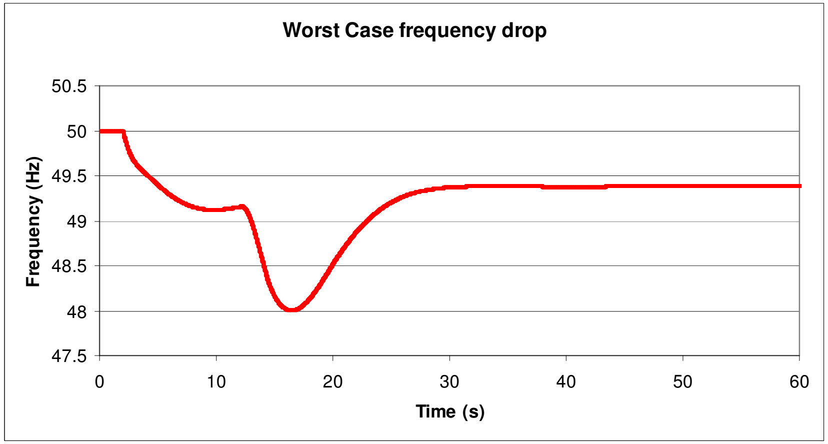
- Following delivery of Active Power to the network a small recovery period shall be permitted *(This will vary with wind speed and requires further analysis)*
- The Dead band settings should be adjustable between 0.02 Hz/s and 0.5Hz/s in steps of 0.01Hz)
- Adequate filtering needs to be installed. df/dt controllers by their very nature can amplify noise. Adequate filtering therefore needs to be put in place to prevent adverse interactions with other Users.

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 managable – examples provided in previous meetings
  - There is no recovery period when operation is at or beyond rated wind speed
- Further discussions with manufacturers to identify what factors affect the recovery period and the potential for minimising its impact

Recovery period





Conclusions

- **High level Proposals developed but major issues in increasing loss to 1800MW**
  - Settings can be developed and proposed for 1320MW
  - 1800MW is a problem – issue for future new build plant ?
- **Rate of Change of System Frequency issues – for discussion with DCRP**
- **Co-ordination with Primary Response to be determined**
  - Speed of Primary Response
  - Static Provision
  - Capability / Delivery in Real Time
- **Issues to be resolved regarding power recovery**
  - Recovery during critical wind speeds
  - Mitigation measures
  - Power recovery limitations based on Transmission System need
- **Further manufacturer engagement and feedback required**
- **Consideration will also need to be given to high frequency events and Repeatibility**