University of Strathclyde

MANCHESTER 1824
The University of Manchester

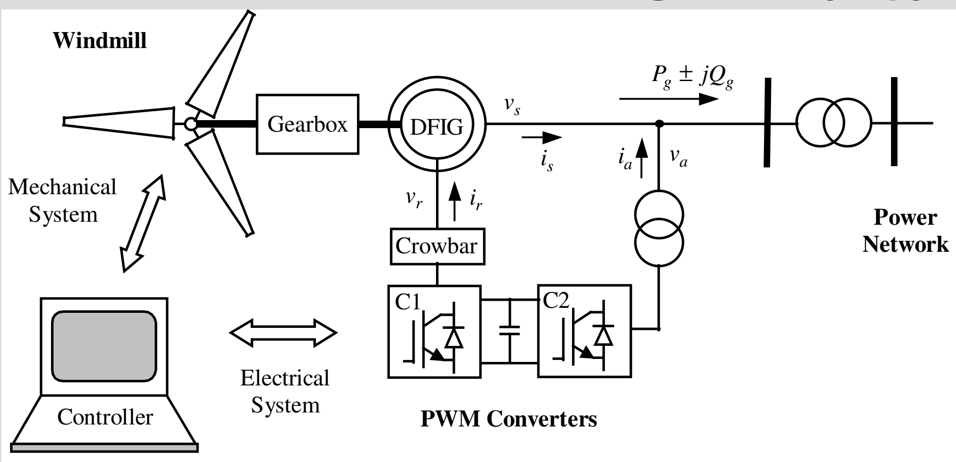
DTI Centre for Distributed Generation and Sustainable Electrical Energy

CONTROL OF DOUBLY FED INDUCTION GENERATORS FOR WIND FARM OPERATION

Summary

In order to meet the Government targets of 10% of UK electricity from renewables by 2010, large onshore and offshore wind farms will be connected using mainly DFIG wind turbines. The main objective of this project is to investigate the impact that large penetration of wind energy will have on system operation, and network dynamic and transient stability. Models of DFIG machines and their controllers are being developed to facilitate wind farm connections that comply with the GB Grid Code, and the issues associated with the intermittency and storage requirements for this new source of energy are also explored.

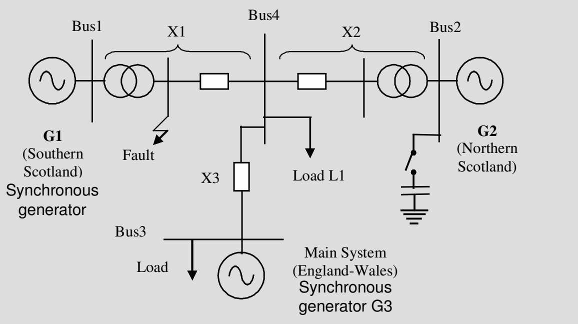
DFIG wind turbine



The DFIG wind turbine comprises a wound-rotor induction generator with the rotor connected to through a variable frequency PWM converter system. Variable operation of the DFIG is achieved by injecting a variable voltage into the rotor at slip frequency.

Influence of wind farms on dynamic stability

Generic network model



Operating conditions

G2 f2	G1 Rating (MVA)	G1 Rating (MW)	G2 Rating (MVA)	G2 Rating (MW)
1	2,800	2,520	2,400	2,240
2/3	3,733	3,260	1,600	1,500
1/3	4,667	4,010	800	750
1/10	5,320	4,536	240	224

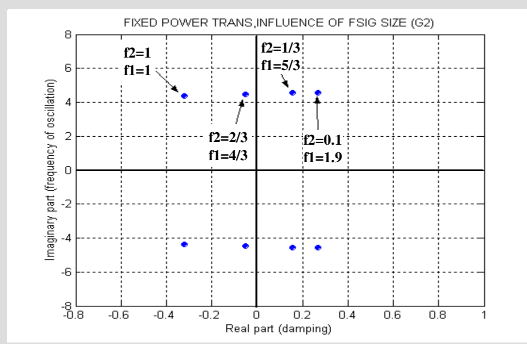
$$f1 = \frac{\text{capacity of generator G1 (MVA)}}{\text{capacity of G1 MVA (2800 MVA)}}$$

$$f2 = \frac{\text{capacity of generator G2 (MVA)}}{\text{maximum capacity of G2 MVA (2400 MVA)}}$$

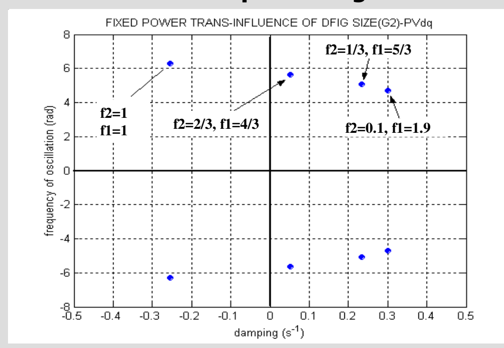
- **A simple three-generator system that is considered representative of the major areas of the UK network has been developed in Simulink to assess the interaction between bulk wind farm and conventional generation and its influence on network dynamic characteristics.**
- **Eigenvalue techniques are used to explore the influence of different levels of wind penetration on dynamic stability by observing the behaviour of the dominant eigenvalues in the complex plane.**
- **The study results show that as the wind generation capacity on the northern Scotland is built up in stages to the full capacity situation (2400 MVA), the dominant eigenvalue is shifted to the left of the complex plane thus enhancing dynamic stability. Both FSIG- and DFIG-based wind farms exhibit this benign behaviour.**

Eigenvalue analysis

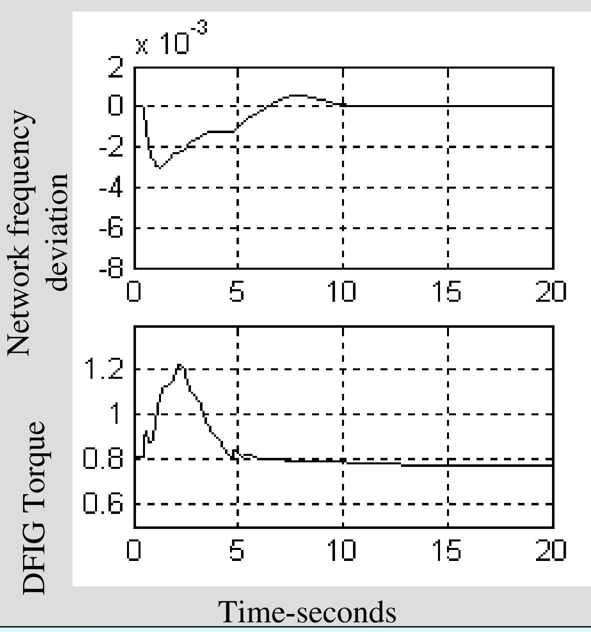
A FSIG wind farm represents generator G2



A DFIG wind farm represents generator G2



Improved network transient stability with DFIG wind farms

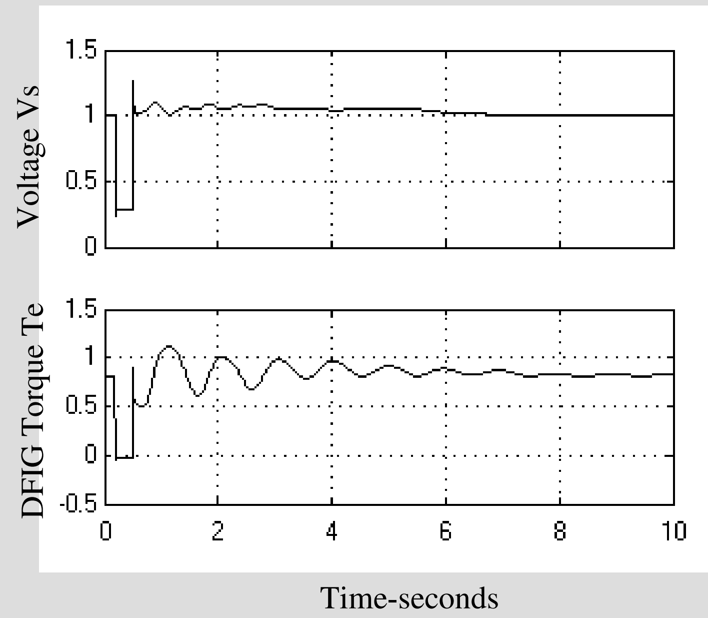


FREQUENCY REGULATION

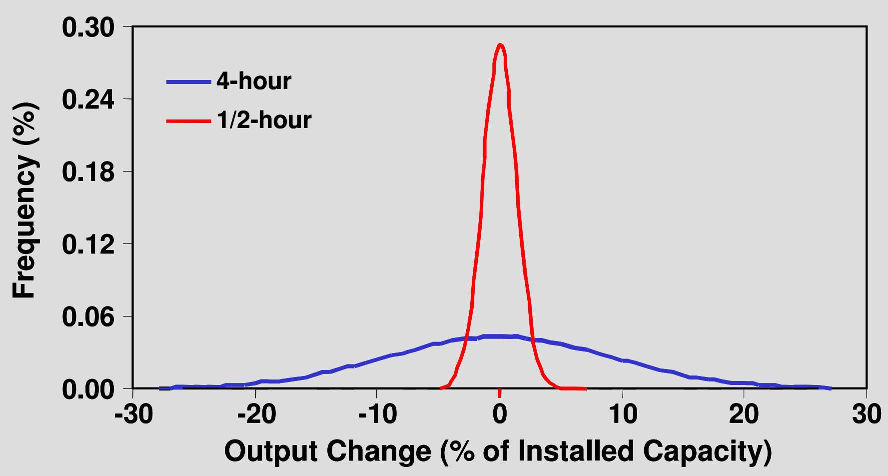
New control schemes being designed for the DFIG enable the wind farm to contribute positively to frequency regulation and overall inertia of the power system following loss of generation. The DFIG delivers energy stored in the shaft to prevent system frequency from falling outside the established limit

DYNAMIC VOLTAGE CONTROL

Transient and dynamic stability of the system are improved with DFIG controllers that provide large wind farms with the capability to provide dynamic voltage and reactive power support following network disturbances. The wind farm is able to ride through the fault exhibiting good terminal voltage control and post-fault recovery performance.



Wind energy intermittency and storage requirements



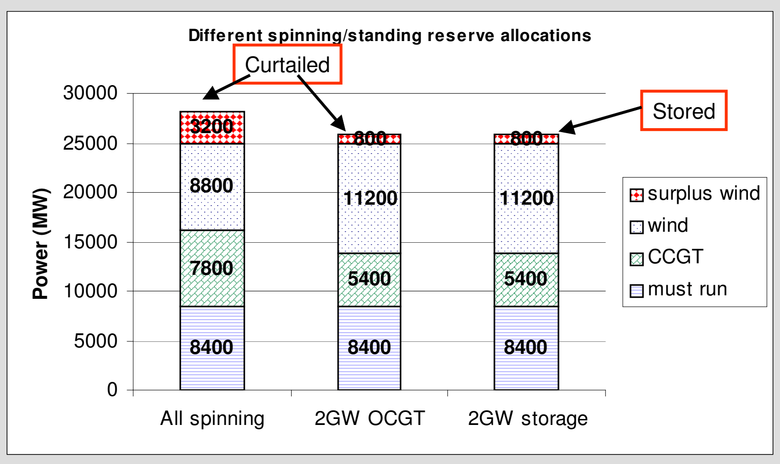
Reserve requirements: 26GW of wind

Based on wind forecast error (persistence based forecast technique). Uses standard deviation (frequency distribution of changes in wind generation output over four hour time horizons).

Lead Time [Hours]	Standard Deviation [MW]	Likely maximum change [MW]	Extreme change [MW]
0.5	360	1,090 – 1,450	2,600
1	700	2,100 – 2,800	3,950
2	1,350	4,050 – 5,400	6,550
4	2,400	7,200 – 9,650	13,500

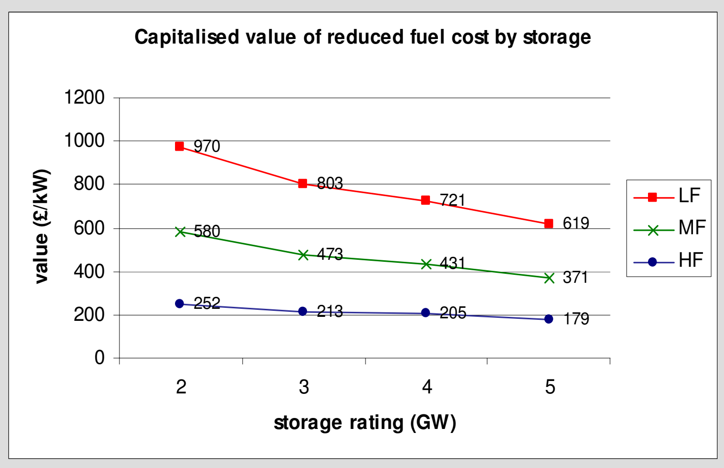
All spinning reserve option
26 CCGT units hold 6,500 MW synchronised reserve and generate 7,800 MW power **...**
Not all the 12,000 MW wind can be absorbed.

With 2000MW Standing Reserve (OCGT /storage)
18 CCGT units hold 4500 MW synchronised reserve and generate 5400MW power **...**
More of the 12,000 MW wind can be absorbed.



Snapshot of system operation

Wind installed	26,000 MW
Expected wind output	12,000 MW
Reserve needed	6,500 MW
Demand	25,000 MW
Inflexible generation	
Must run	8,400 MW
CCGT units	
Rated output	550 MW
mSG	300 MW
OCGT/storage capacity	2,000 MW



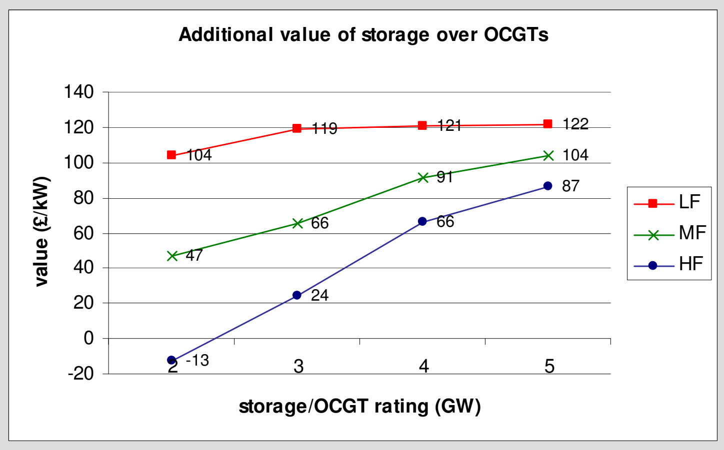
Real time operation: simulations for low, medium, and high flexibility generation systems show high storage value for LF.

Advantage of storage over OCGTs:

Ability to store excesses in wind generation during periods of high wind and low demand.

Disadvantage of storage against OCGTs:

Energy stored depends on charge & discharge regime so not 100% availability - more spinning reserve required than with OCGTs.



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