MEDOW

MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

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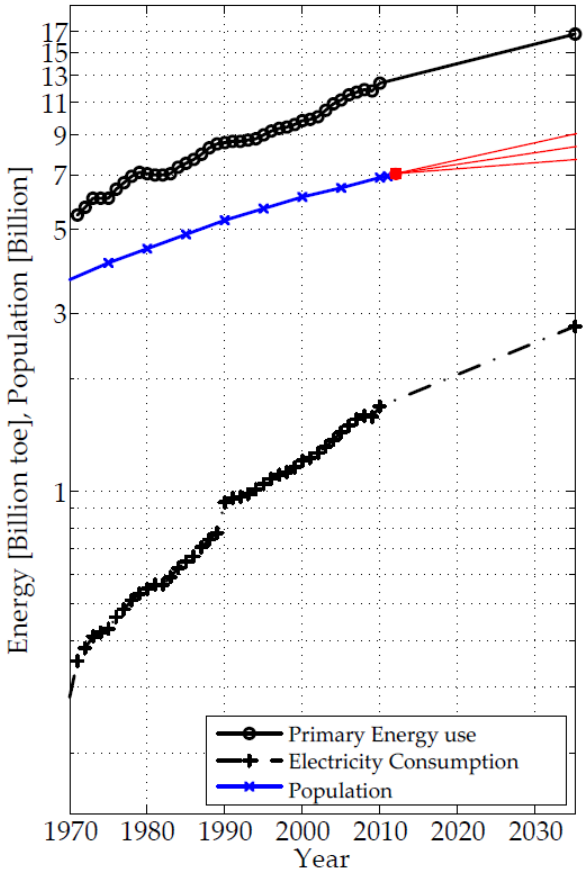
Introduction

- Energy is a key component to modern societies and the need for energy is increasing worldwide, while electricity supply is becoming ever more important
- In 2010, the world consumed 12.32 billion toe[1], in comparison to 7.10 billion toe in 1980: an annual increase of 1.85%.
- In the same period, the world population grew 1.44% annually from 4.5 to 6.9 billion.
- On the other hand, electricity consumption experienced a much stronger annual growth (3.83%), increasing from 6,371 TWh in 1980, to 19,665 TWh in 2010 [1]
- Fossil fuels, Oil, coal and natural gas accounted together for 81.1% of all the world primary energy use in 2010



1 A tonne of oil equivalent (toe) is defined as11.63 MWh.
12.32 billion toe 140, 000 TWh

[1] International Energy Agency, "World Energy Outlook," IEA, Paris, Technical Report, 2012, ISBN: 978-92-64-18084-0.

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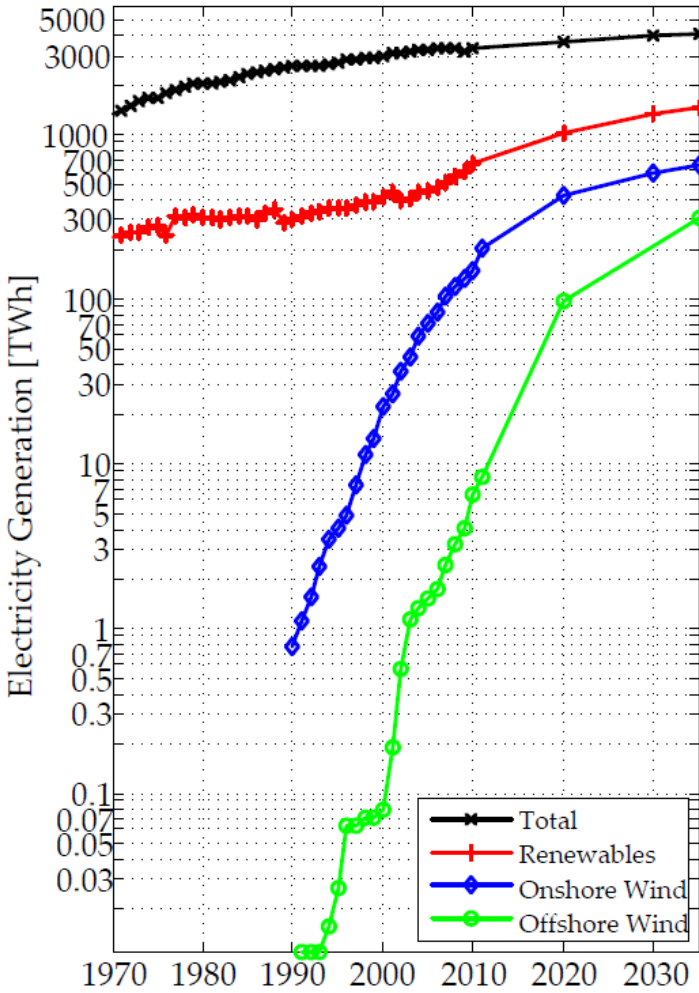
EU Policies and Regulatory schemes

- 20% greenhouse gas emissions reduction from 1990 levels; 20% energy consumption from renewable sources; 20% energy efficiency improvement

- According to the EU-27 National Renewable Energy Action Plans:
  - Wind energy has the potential to supply 41% of all renewable electricity;
  - Whereas offshore wind energy will account for 28% of the entire wind energy share

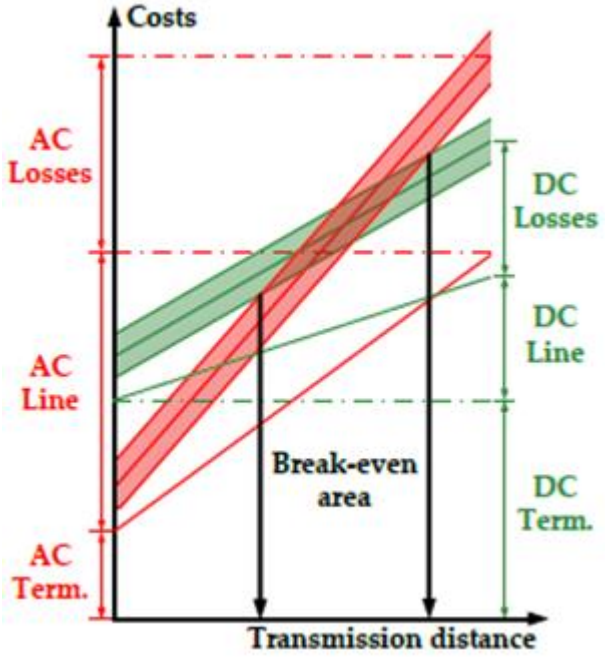
- Between 1995 and 2005, total wind energy installed capacity in Europe rose from 2.5 to 40.5 GW, a 32.1% annual average growth



European Wind Energy Association, "Oceans of Opportunity," EWEA, Brussels, Technical Report, 2009

Transmission Technology

- The best sites for exploitation of renewable resources are usually remotely located from demand centres
- Underground and submarine HVac transmission cables suffer greatly from losses due to charging currents.
- The North Sea offshore transnational grid is anticipated to be built as a high-voltage multi-terminal dc (MTdc) network
- Additionally, almost 30% of all the electricity presently generated is converted from ac to dc before it is actually used
- In the next two decades, conversion from ac to dc is predicted to rapidly increase to a staggering 80%



Multi-terminal DC grid for offshore wind (MEDOW)

MEDOW is a Marie Curie Initial Training Network (ITN) consisting of 11 partners (5 universities and 6 industrial organisations) with collective expertise on the manufacturing, design, operation, and control of multi-terminal DC grids.

MEDOW is funded by the European Commission, People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme (FP7/2007-2013)

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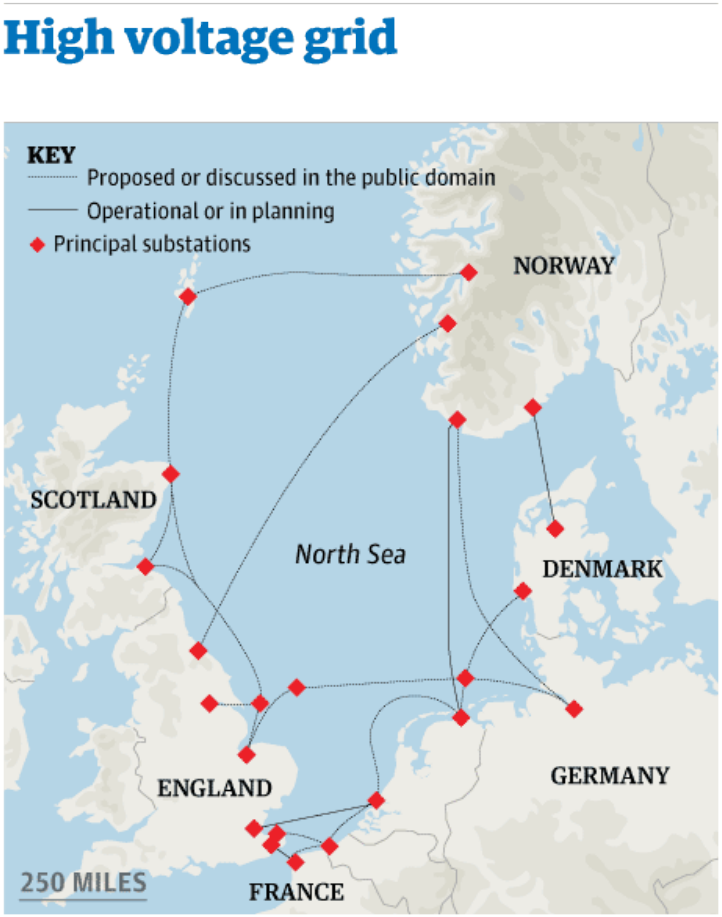
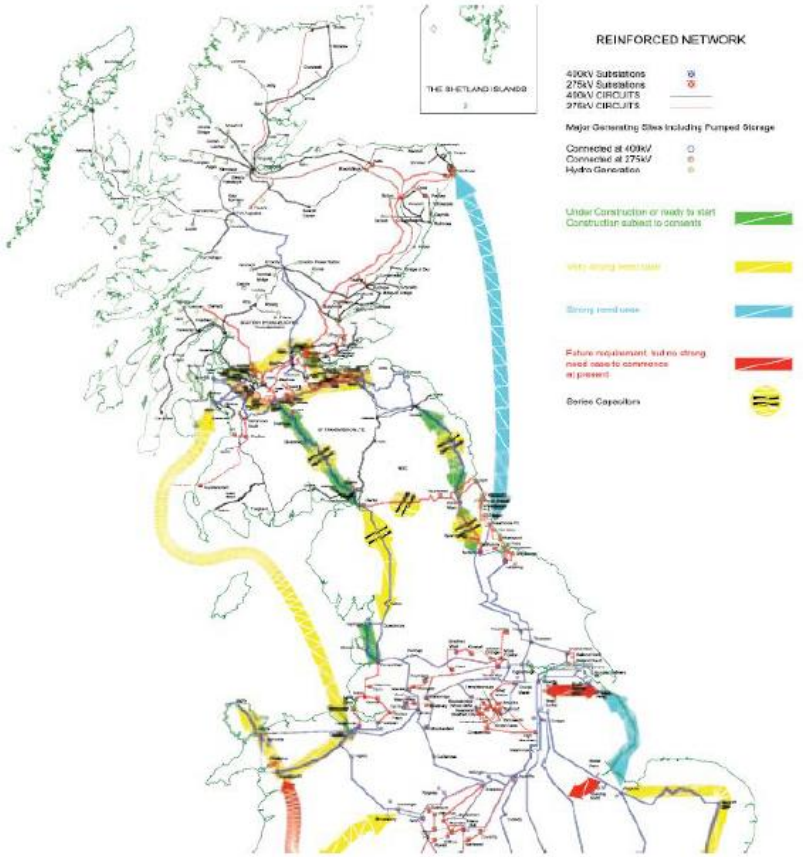
Planned Network Reinforcement for 2020

Major reinforcement include series compensation of major transmission routes and two additional HVDC links between Scotland and England



North Seas Countries' Offshore Grid Initiative, "Final report - grid configuration," NSCOGI, Technical Report, November 2012



Electricity Networks Strategy Group, "Our Electricity Transmission Network: A Vision for 2020," Electricy Networks Strategy Group, 2009.

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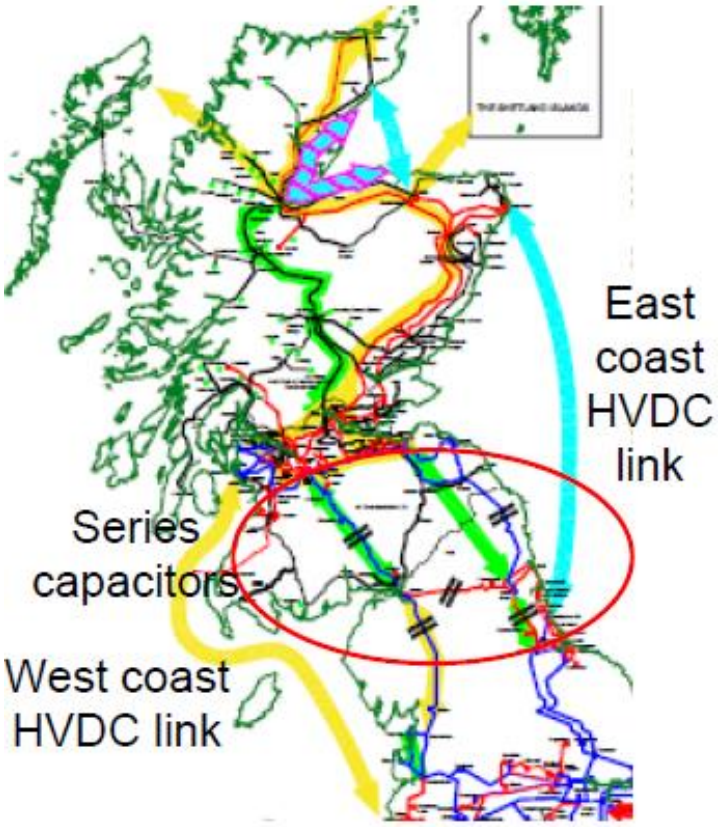
Planned Network Reinforcement for 2020

Scotland is currently linked to England/Wales through a transmission corridor having a capacity of 2200 MW.

Due to an increase in onshore/offshore wind penetration and population growth the transfer capacity of this region must be increased

Submarine connection through CSC and VSC HVDC transmission and onshore reinforcements of North-South circuits (via series compensation) are considered



CSC: Current Source Converter
VSC: Voltage source Converter

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Planned Network Reinforcement for 2020

Series Compensation

•Series capacitors are often built into AC transmission lines to compensate for the line inductances over long distances.

•A series compensation system is far more economical than building additional transmission lines and bypasses the requirement for planning and way leave issues.

•Extensive series compensation of existing AC transmission lines is planned in areas where additional power capacity is needed.

HVDC Links

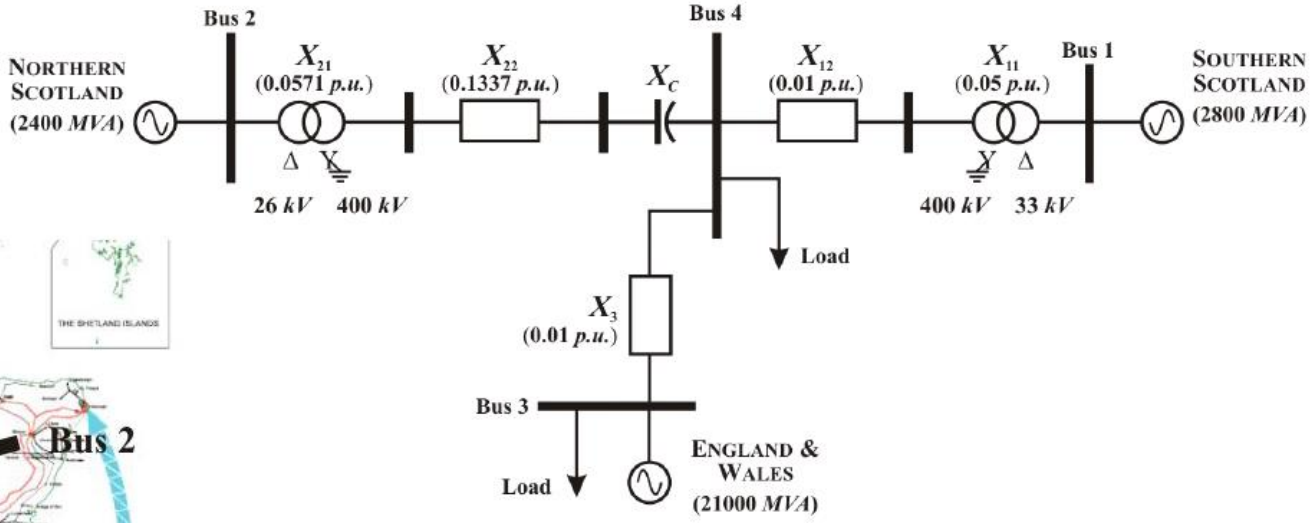
•HVDC links could provide addition submarine transmission routes from north to south without the problems associated with new pylon installations.

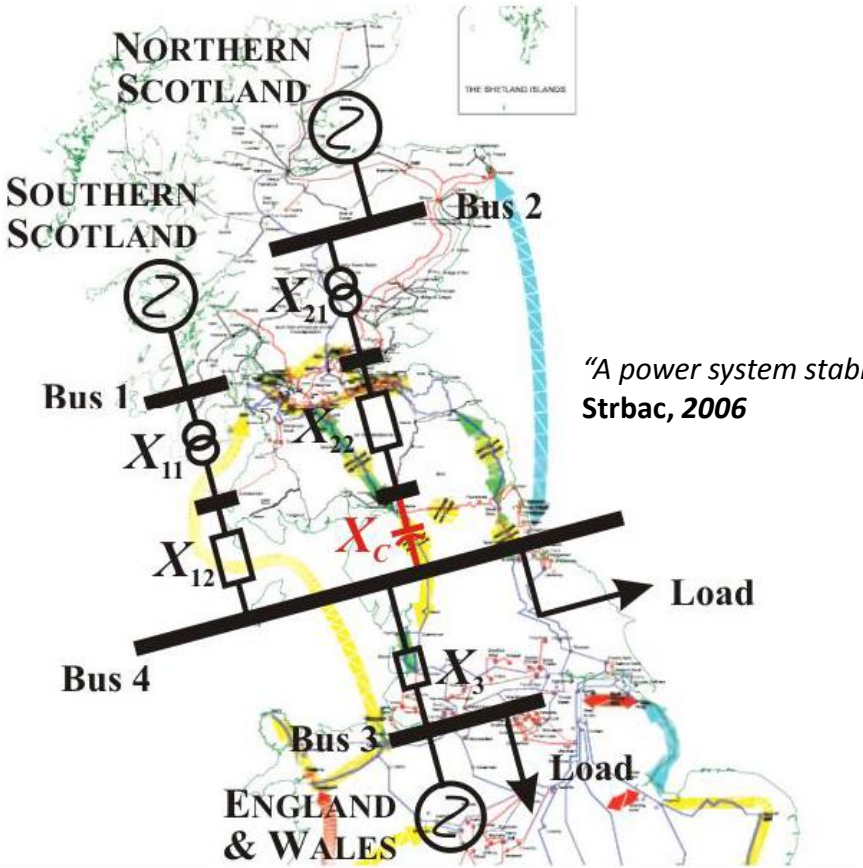
•Potential benefits to the AC system in terms of stability and reactive power control.

•Two HVDC links are planned to transmit bulk power from Scotland to England:

- Eastern -Peterhead (Scotland) to Hawthorne Pit (England) (2.8 to 6.6 GW)
- Western -Hunterston (Scotland) to Deeside (England) (2016)

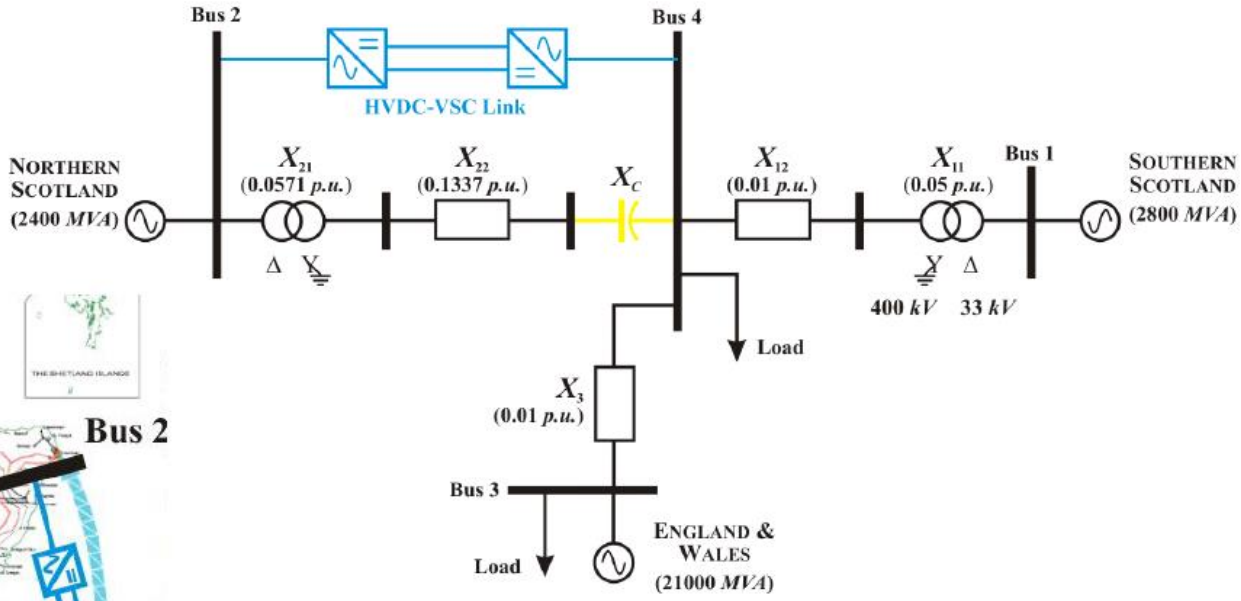
The Three Machine Generic Model

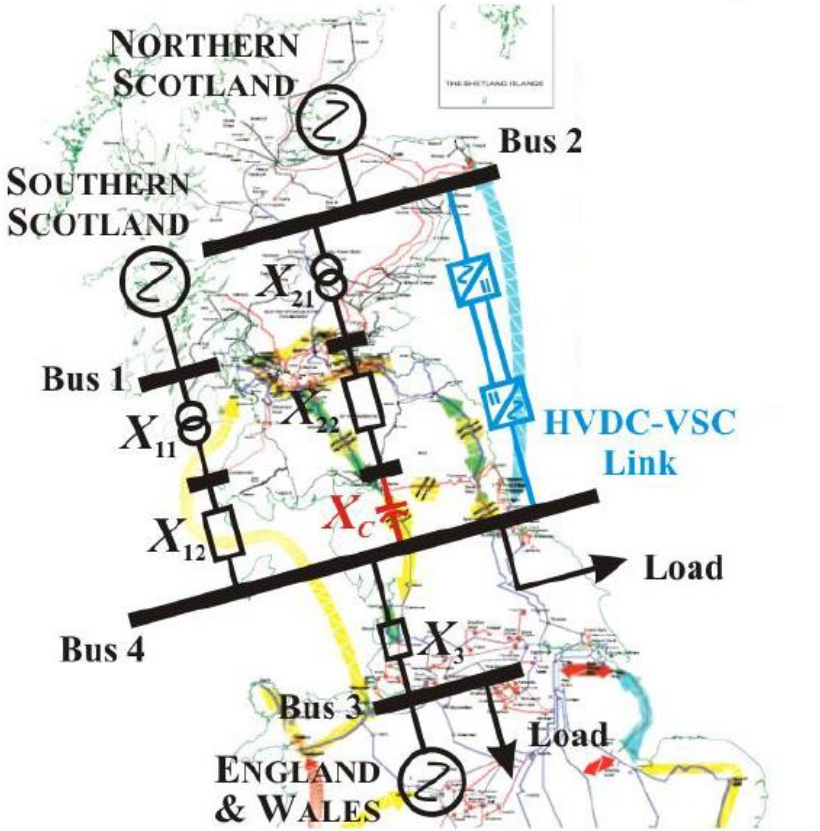




"A power system stabilizer for DFIG-based wind generation" **Hughes, Anaya-Lara, Jenkins and Strbac, *2006***

The three machine generic model with HVDC link





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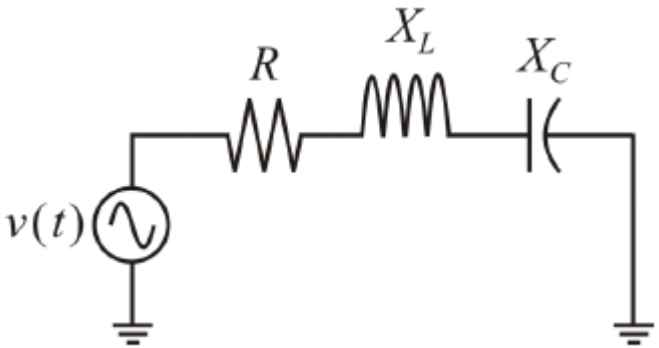
Subsynchronous Resonance (SSR) threat

Subsynchronous Resonance (SSR)

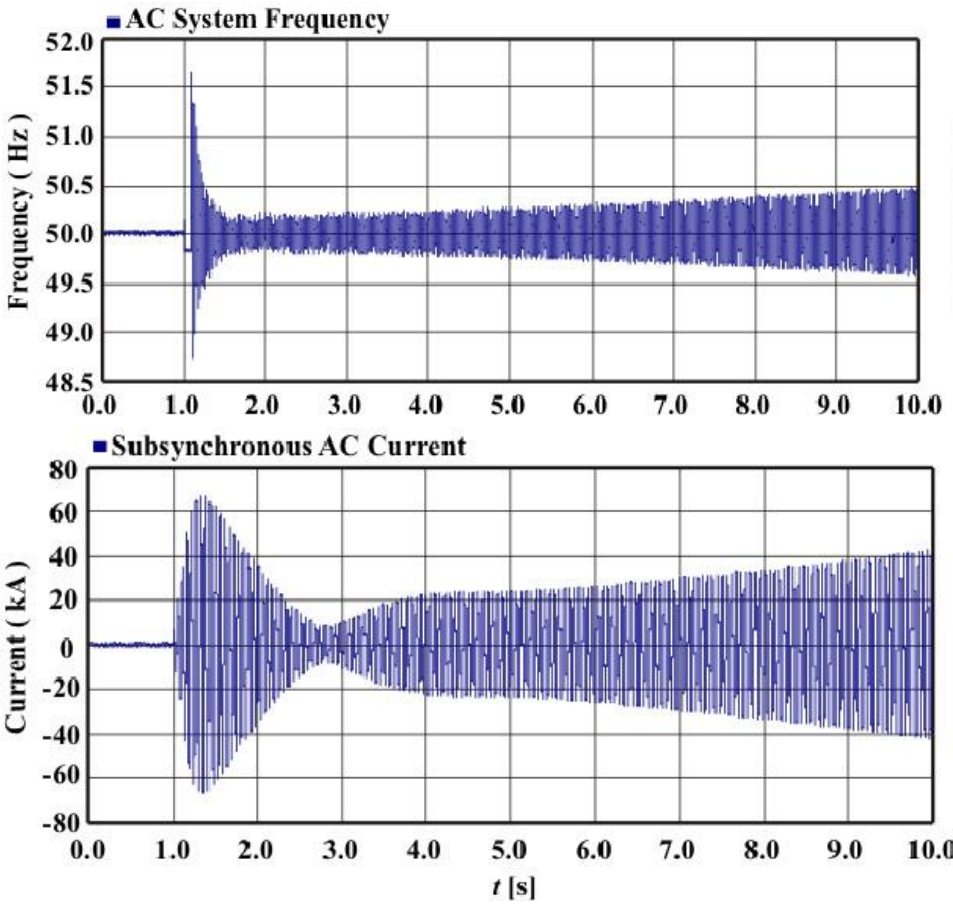
"… is an electric power system condition where the electric network exchanges energy with a turbine generator at one or more of the natural frequencies of the combined system below the synchronous frequency of the system."



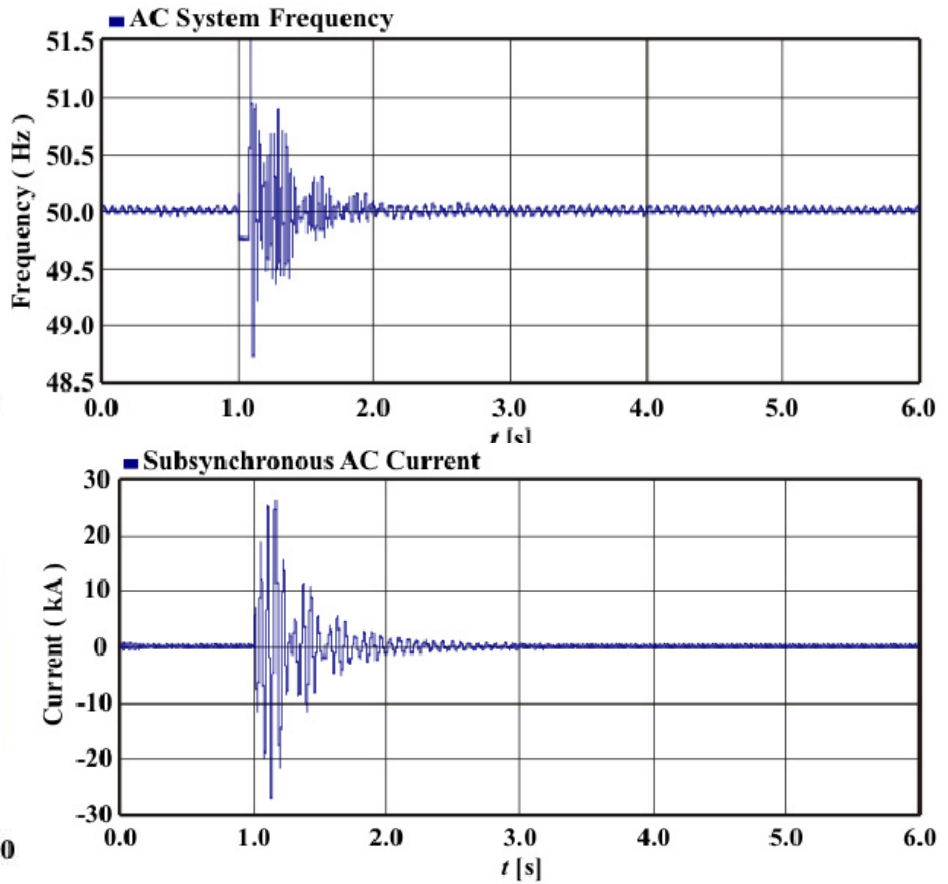
Consequences: the Mohave Generating Station.

SSR mainly occurs in series capacitor-compensated transmission systems.

Results



Without damping from HVDC



With damping

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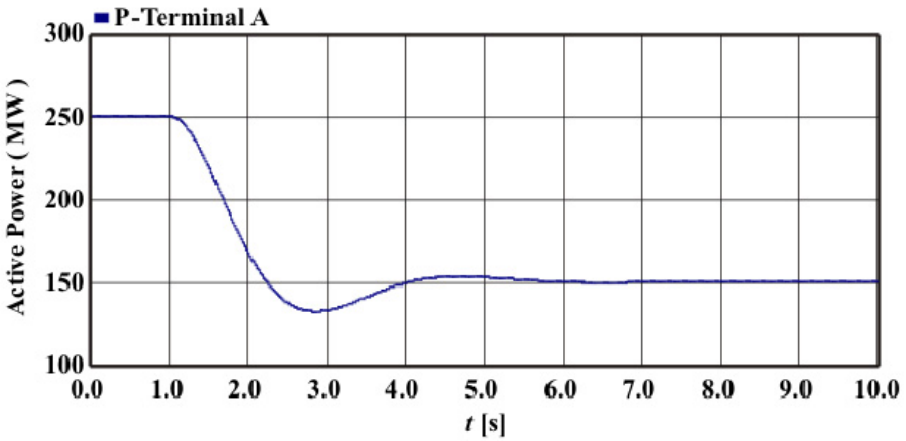
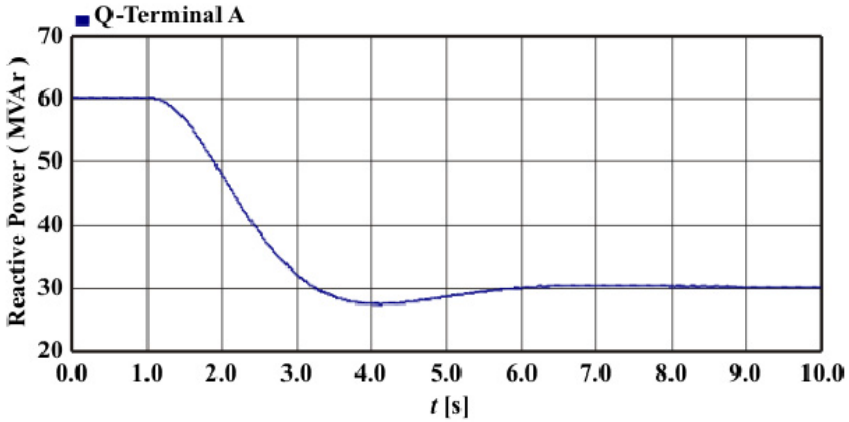
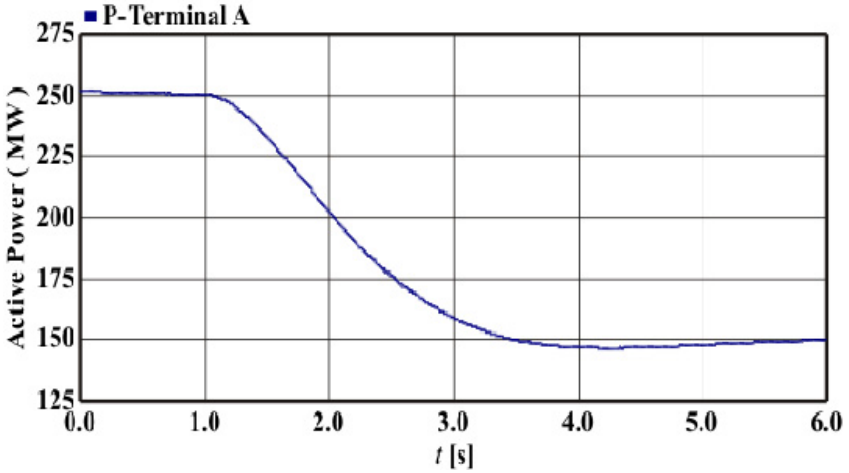
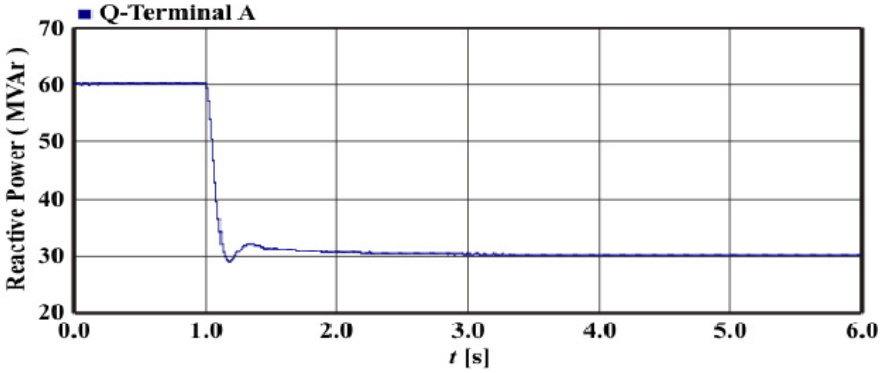
Results Contd…





Without damping from HVDC





With damping

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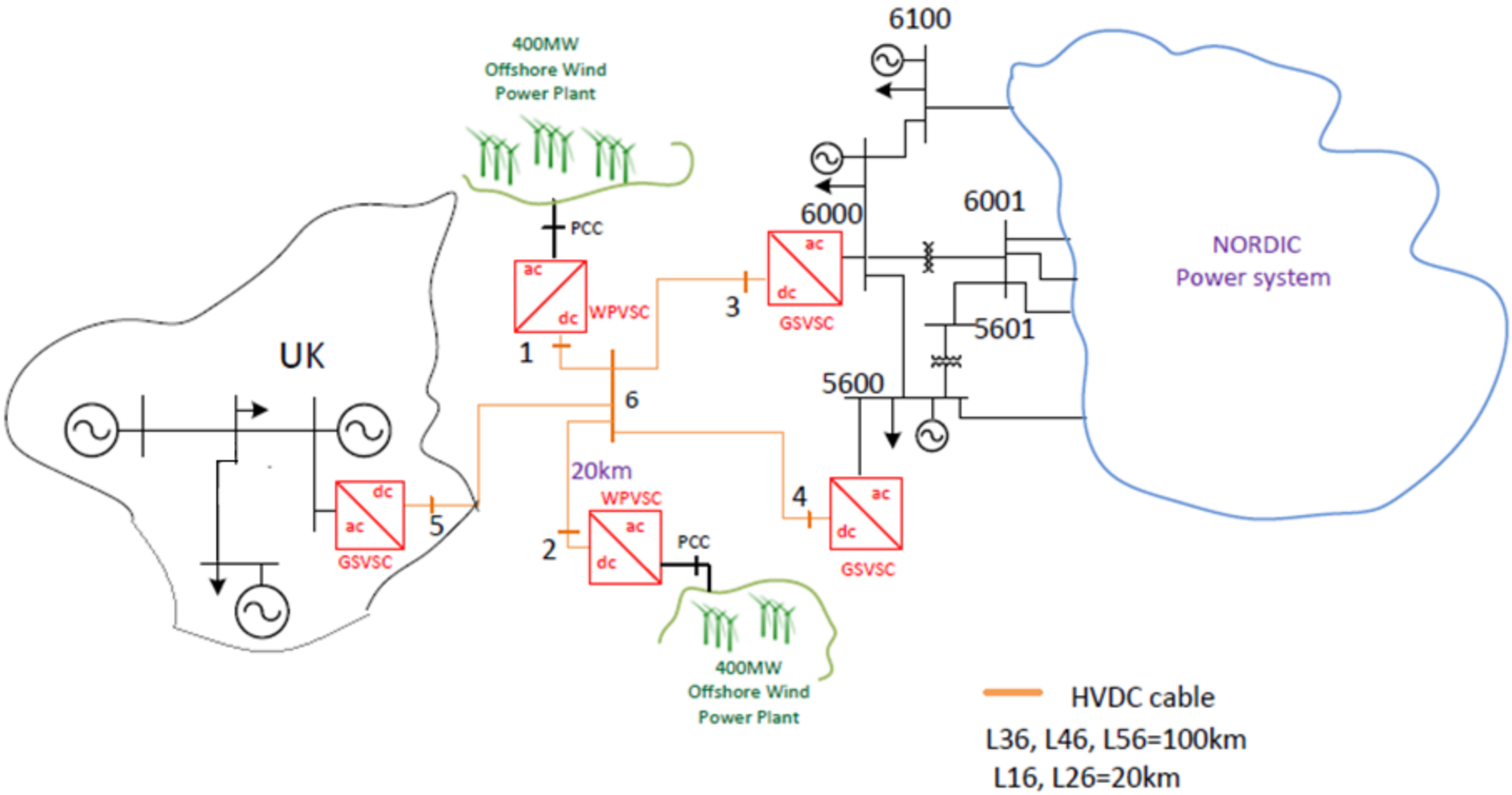
Conclusion

- The proposed reinforcements for the GB transmission network for 2020 include onshore series compensation and offshore HVDC links.
- The adverse effects in the form of SSR introduced by series compensation in a three-machine network, resembling the operation of the mainland GB system in the 2020, have been examined.
- Moreover, SSR mitigation has been achieved through a VSC-HVDC link
- The HVDC link was modelled to provide its primary control objective and an auxiliary function for SSR damping.
- As VSC-HVDC converters are utilised more in the future, their flexibility can be used to damp power system oscillations in adjacent AC transmission systems.
- This may be cost effective by eliminating the requirement for additional power electronics equipment (such as TCSCs)

Future work



http://www.eirgrid.com/aboutus/eirgridtv/east-westinterconnectoranimation/

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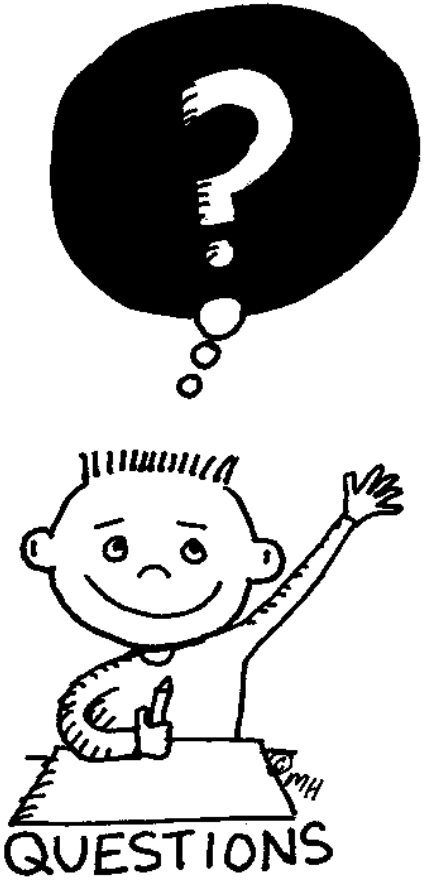
THANKS FOR YOUR ATTENTION



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