Optimising AC and DC Transmission Networks for High Penetration of Renewables

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Challenges of a power system with Renewables

- The resource is often remote from loads and exploiting geographical diversity requires energy transport capacity.
  Transmission
- Ancillary services are supplied traditionally by large fossil generation.
  Generation
- Renewable generation often consists of smaller units connected through power electronic converters.
  Renewable Plant

Photo RES

Transmission for Renewables

- Permission for Overhead Line circuits is very difficult to obtain
- What Security and Quality of Supply Standards should be adopted?

  GB plans to N-2 security. For renewables:

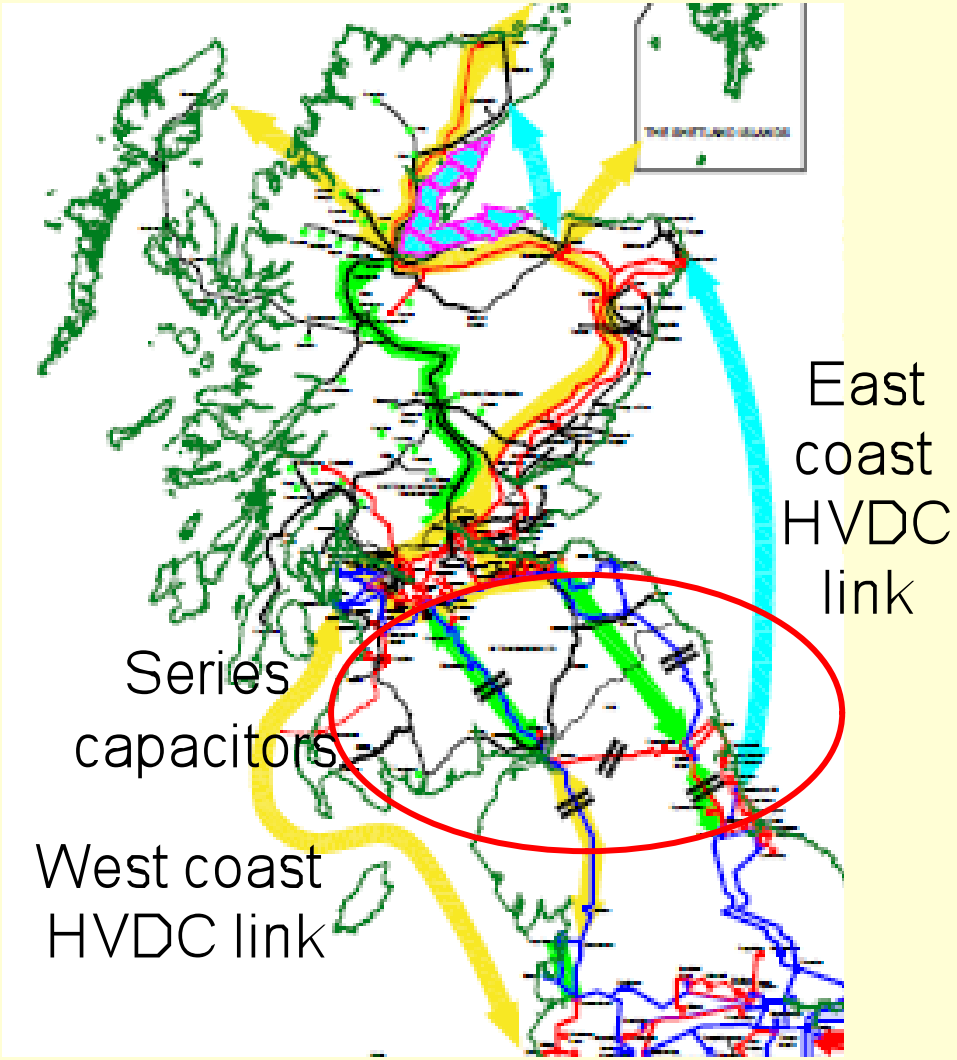
  Is N-1 or even N-0 appropriate?

  Is “connect and manage” appropriate?

  Reducing security will increase losses
- What Technology should be used
  - AC or DC Transmission?
  - Overhead or underground?
  - Passive or active transmission circuits?

Photo RWE npower renewables

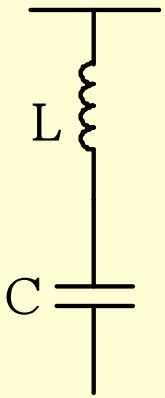
GB North South Transmission Reinforcements



- GB Onshore wind resource is mainly in Scotland
- Load is in London – major North South bottleneck
- It takes typically 10 years to build a new 400 kV overhead line
- Solutions
  - Two submarine HVDC circuits (one current source and one voltage source)
  - Use of series capacitors to reduced line inductive reactance and increase capacity.

Graphic National Grid

AC system shunt compensation



In an AC transmission system we can think of Real and Reactive Power as 2 quantities
Real power does work
Reactive power is associated with electric and magnetic fields
Reactive power controls the voltage of a transmission system

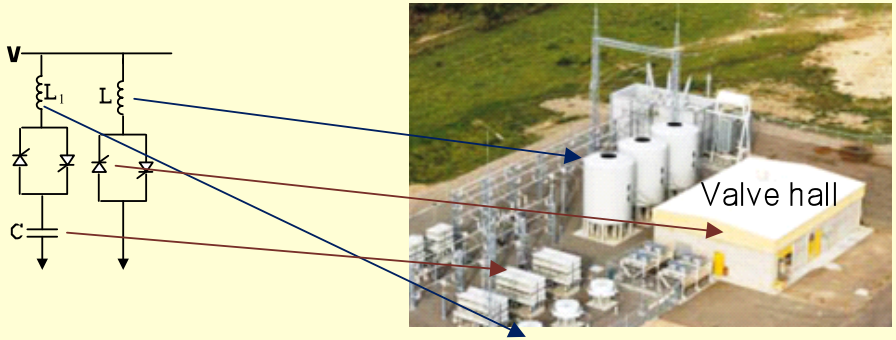
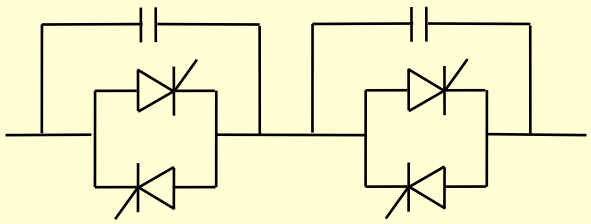


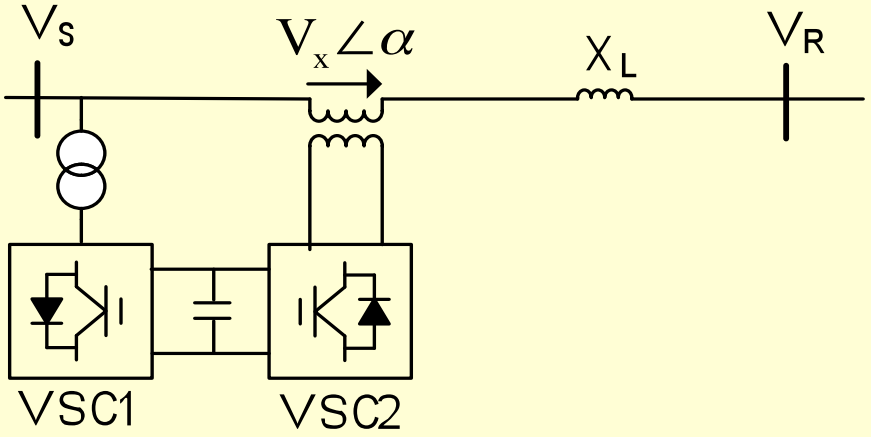
Photo Toshiba

Increasing capacity and controllability of AC lines

- AC transmission systems are inductive rather than resistive.
- Current flows are controlled by the generation and loads (not by controls within the network)
- Circuit capacity can be increased by compensating for the inductance using series capacitors (but at the risk of resonance)
- Power electronic controls (FACTS) have been demonstrated but have not achieved commercial success



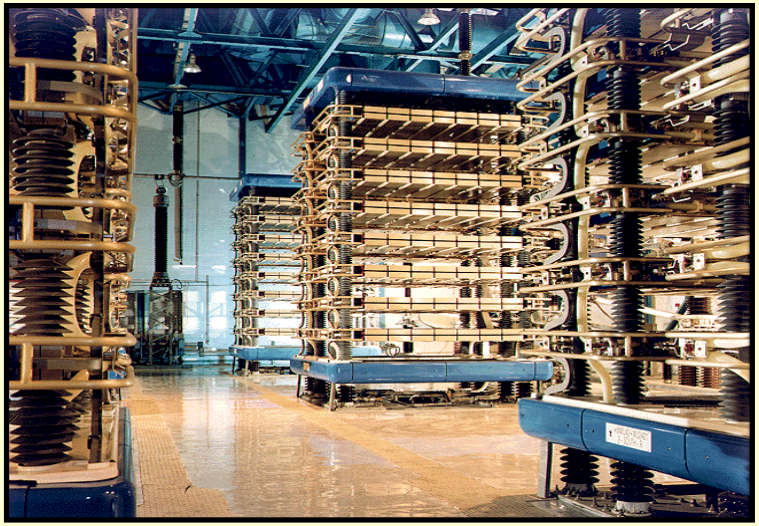
Thyristor controlled series capacitor



Unified power flow controller

HVDC Transmission

- Current source HVDC (using thyristors) is an established technology
- Point-point links available up to 6 GW +/- 800 kV (overhead line)
- Example is the Pacific Intertie
- HVDC is essential for large submarine cable links (due to high Capacitance of cables)
- Low losses in converters
- No redundancy but usually in a bipole configuration
- Not used for multi-terminal schemes



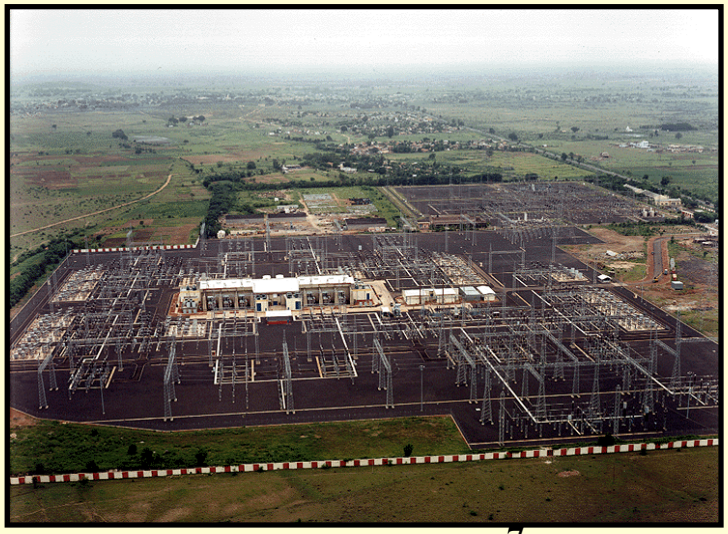
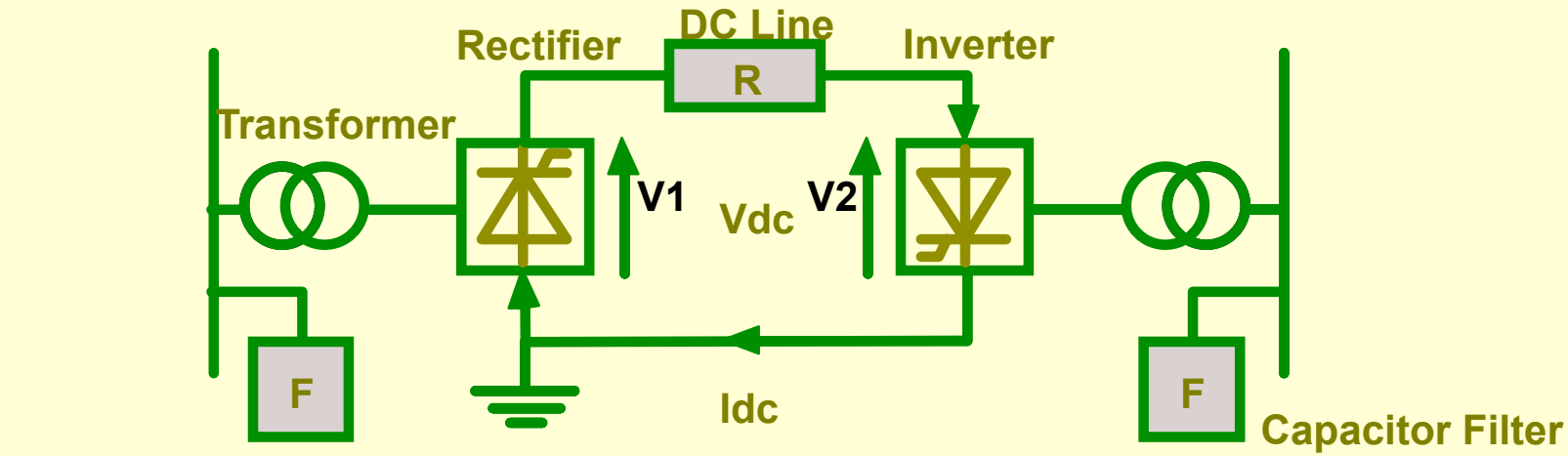
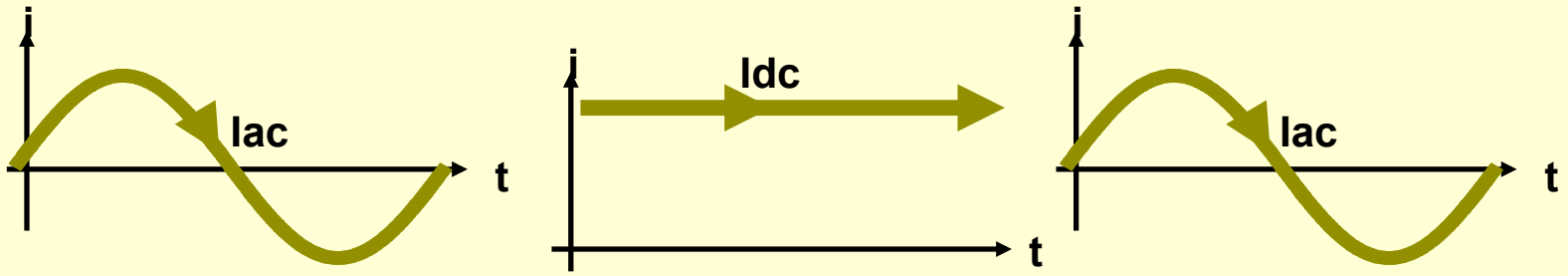


Photo ALSTOM Grid

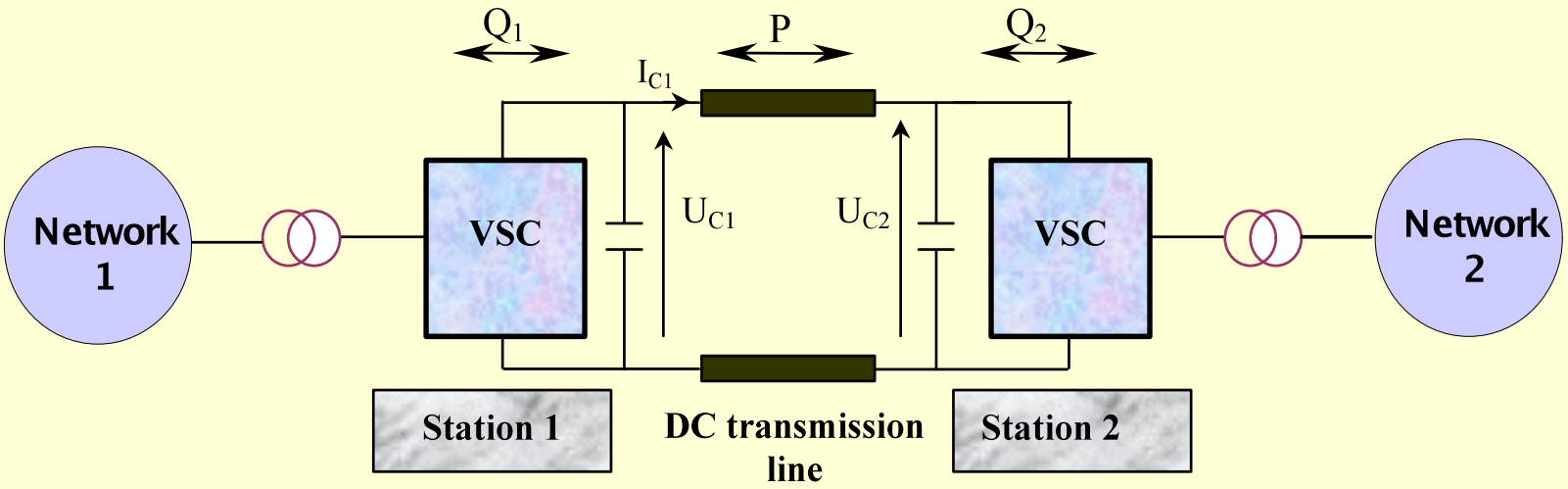
Basic current source HVDC Transmission





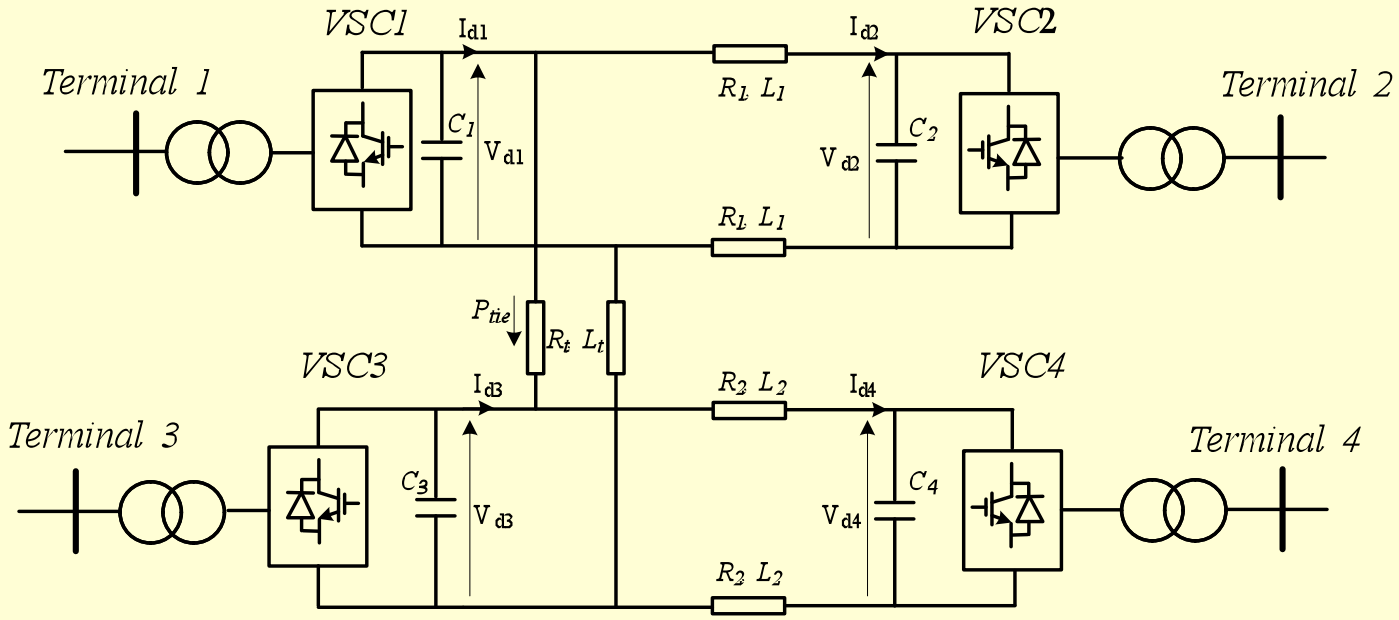
$$Idc = \frac{V1 - V2}{R}$$

Voltage source HVDC using IGBTs



Uses Transistors not Thyristors, 400 MW scheme in San Francisco
Reverses power by changing direction of direct current (not voltage)
Independent control of real and reactive power into AC networks
Very rapid flexible control
Significant electrical losses (now being addressed by manufacturers)
Available up 600MW-1 GW (using cables)
Evolving technology
Expectation that this will be used for multi-terminal schemes

Multi-terminal HVDC



Anticipated for North Sea Grid

Still in research (no demonstrations using VSCs)

Major questions about

- **Performance with DC faults**
- **Loss of power in-feeds into AC network**
- **Compatibility of different manufacturers solutions**

Conclusions

- Very major increases in transmission capacity will be required (UK£4b spend anticipated by 2020)
- At present main cost driver of transmission is contingencies
- This leads to redundant circuits and a reliable low loss transmission system (at considerable expense)
- Regulatory question is whether to relax these constraints for renewable generation
- Power electronic transmission solutions are emerging but these are not cheap, small or low loss.
- Offshore power collection and transmission is particularly challenging

Photo RWE npower renewables

Photo Vattenval