

INTRODUCTION

- Offshore wind connected at distances greater than 50 Km typically VSC HVDC
- VSC-HVDC – Voltage Sourced Converter HVDC
- What are the Alternatives?
- LFAC – Low Frequency AC transmission, typically at 16.7 Hz
- Why LFAC?
 - Transmission distance increased
 - Uses standard AC technology offshore
 - No offshore converter

- Transmission capability stability limit:
 $P_{max} = \frac{V^2}{X}$; $X = 2\pi fL$; $\downarrow f, \downarrow X, \uparrow P_{max}$

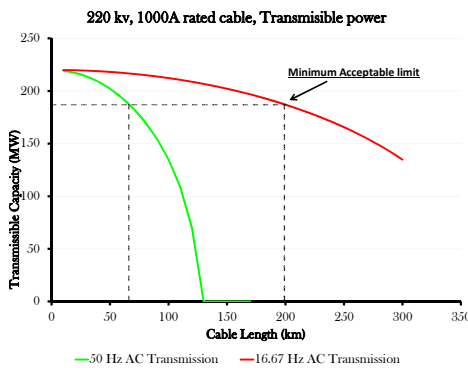


Fig. 1 Power Transfer Capability

METHODOLOGY

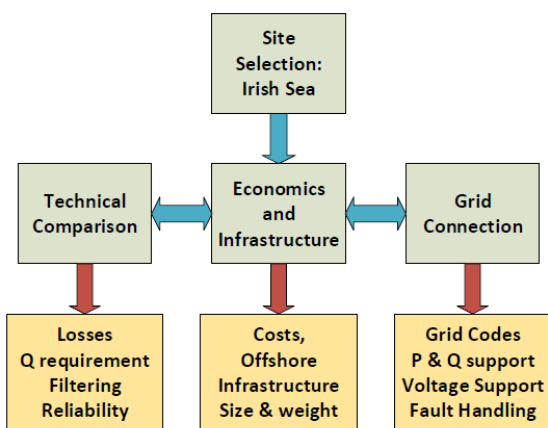


Fig. 2 Comparison and Analysis of the two configurations

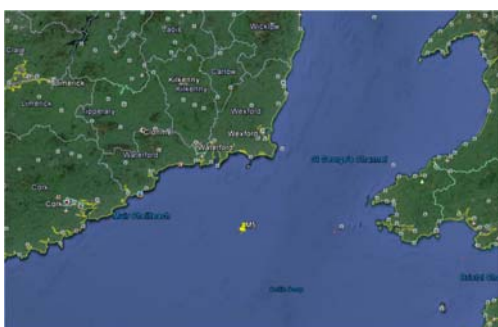


Fig. 3 Site in the Irish Sea

LFAC AND VSC HVDC CONFIGURATIONS

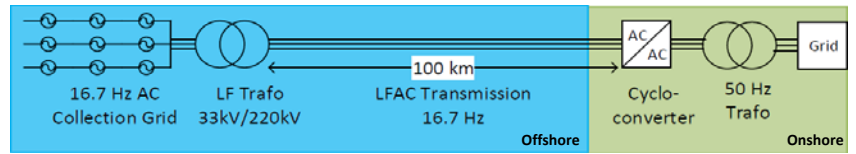


Fig. 4 LFAC collection grid with LFAC transmission at 16.7 Hz

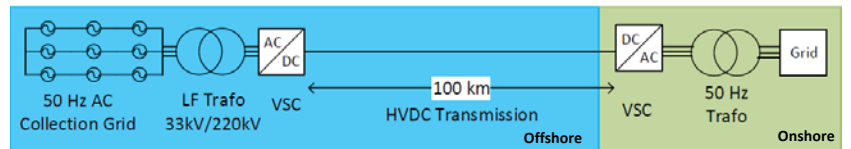
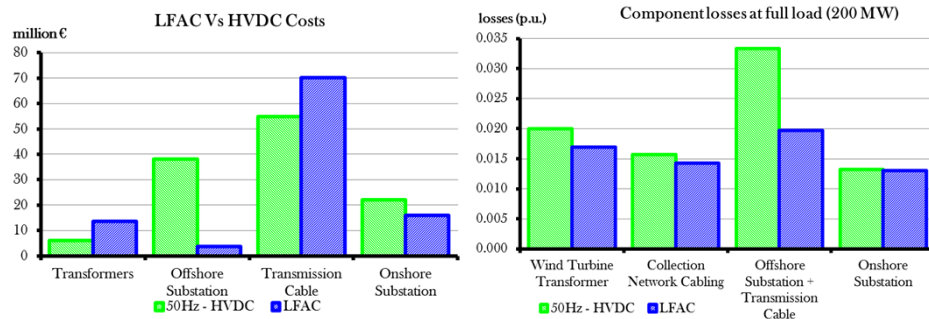


Fig. 5 50 Hz AC collection grid with VSC – HVDC Transmission

RESULTS



Total Costs

LFAC = 103.25 M€
VSC-HVDC = 120.68 M€

Total Losses

LFAC = 12.79 MW
VSC-HVDC = 16.43 MW

VSC – CYCLOCONVERTER TECHNOLOGY COMPARISON

Technology/Characteristic	VSC	LFAC Cycloconverter
Semiconductor	IGBT	Thyristor
Power Control	Independent P and Q	P only not independent
AC filters	Yes (small)	Yes (large)
Min Short Circuit ratio	0	>2 (strong grid)
Black Start Capability	Yes	No
Weak System Performance	OK	Commutation failures

LFAC CONCERNS

- Transformers larger offshore – sizing issue
- Onshore Cycloconverter uses thyristor based technology – filtering issues
- Large footprint – large filters and converter station
- No Dynamic reactive power control without external compensation
- Grid code compliance - Does it need a STATCOM to connect to the grid?

CONCLUSIONS + FUTURE WORK

- LFAC seems favourable over VSC-HVDC in terms of losses and costs
- Grid connection is an issue, VSC compliant without aux. equipment
- Future work: Filtering requirements of Cycloconverter
- EMT (Electromagnetic Transient) simulation of grid connection

ACKNOWLEDGEMENT

This work was conducted in the Electricity Research Centre, University College Dublin, Ireland, which is supported by the Electricity Research Centre's Industry Affiliates Programme (<http://erc.ucd.ie/industry/>). Jonathan Ruddy is funded through Science Foundation Ireland under Grant Number SFI/09/SRC/E1780. Ronan Meere is supported by the Programme of Research in Third Level Institutions PRILI (Cycle 5) and co-funded under the European Regional Development Fund (ERDF).