Key factors in expanding HVDC Multi-Terminal Systems

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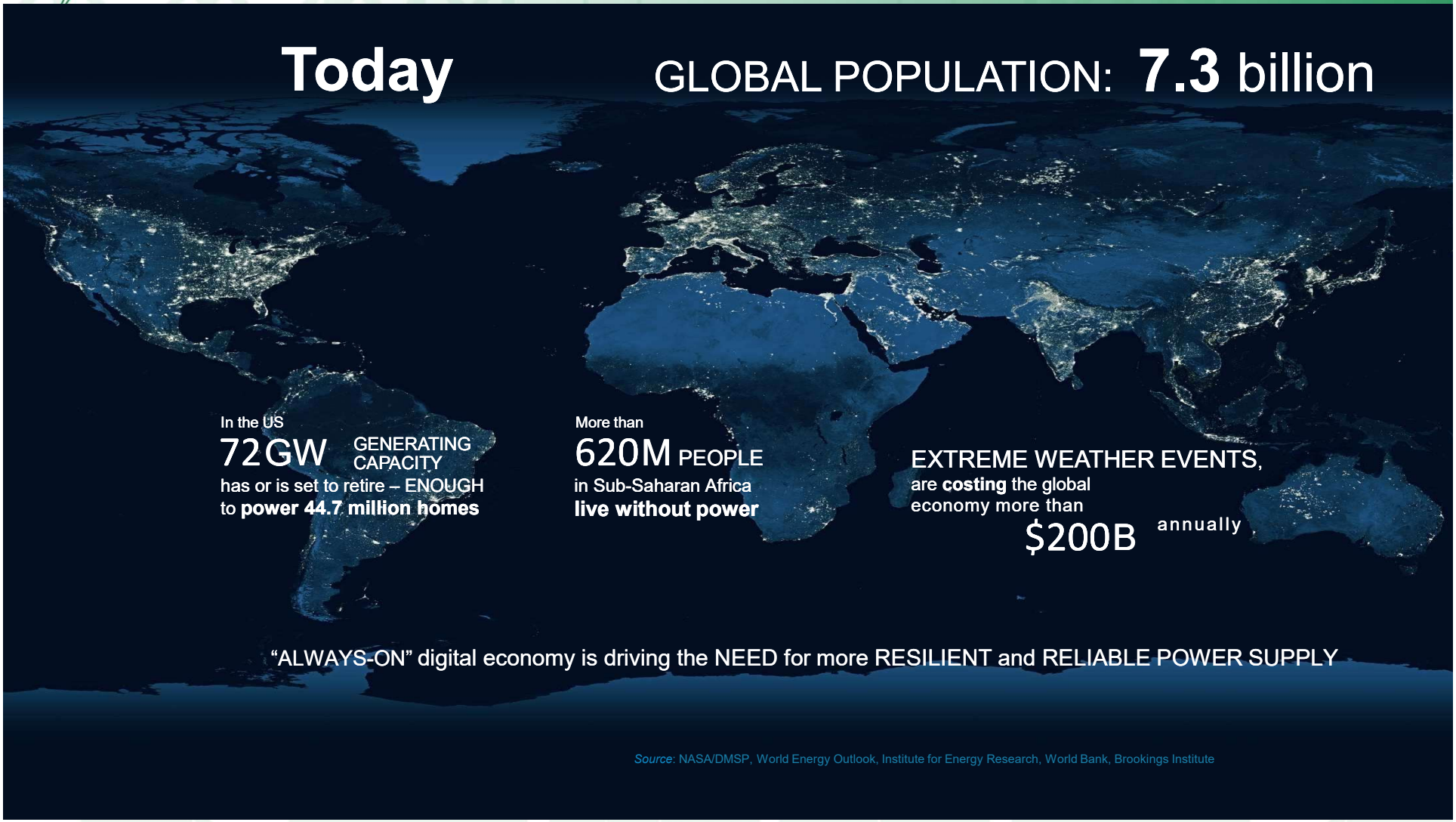
Agenda

- The World is changing
- HVDC Interconnectors helping to support Energy Demand
- HVDC Multi-Terminals – thinking and planning ahead
- How about the future?

Today

GLOBAL POPULATION: **7.3** billion



In the US
72GW GENERATING CAPACITY
has or is set to retire – ENOUGH
to **power 44.7 million homes**

More than
620M PEOPLE
in Sub-Saharan Africa
live without power

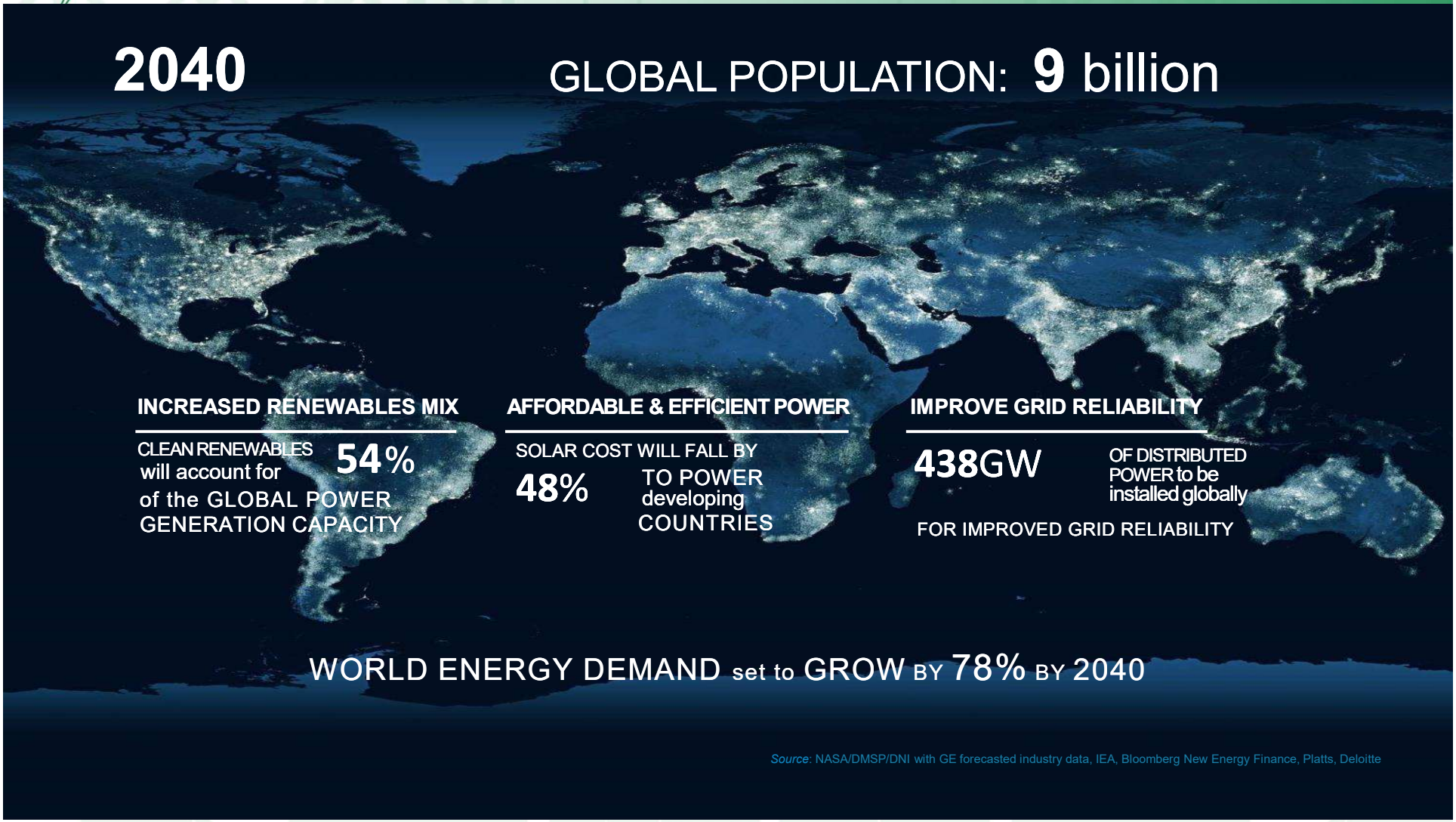
EXTREME WEATHER EVENTS,
are **costing** the global
economy more than
$200B annually

"ALWAYS-ON" digital economy is driving the NEED for more RESILIENT and RELIABLE POWER SUPPLY

Source: NASA/DMSP, World Energy Outlook, Institute for Energy Research, World Bank, Brookings Institute

2040

GLOBAL POPULATION: 9 billion



INCREASED RENEWABLES MIX

CLEAN RENEWABLES will account for **54%** of the GLOBAL POWER GENERATION CAPACITY

AFFORDABLE & EFFICIENT POWER

SOLAR COST WILL FALL BY **48%** TO POWER developing COUNTRIES

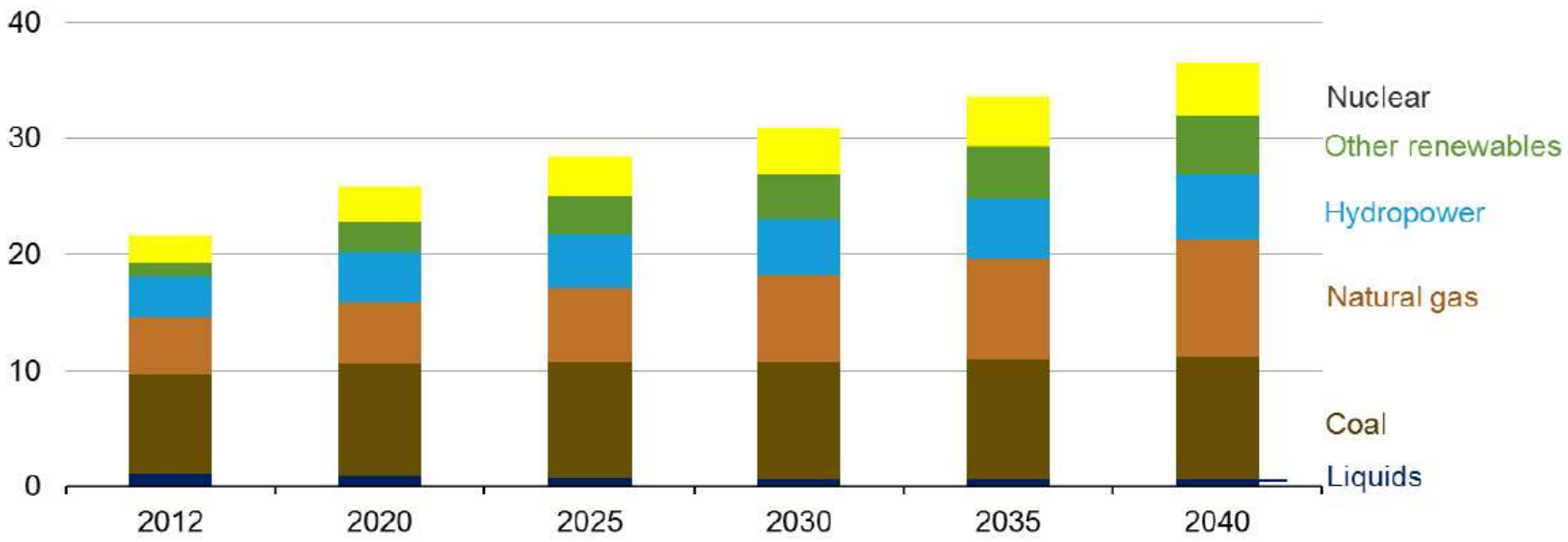
IMPROVE GRID RELIABILITY

438GW OF DISTRIBUTED POWER to be installed globally FOR IMPROVED GRID RELIABILITY

WORLD ENERGY DEMAND set to GROW BY 78% BY 2040

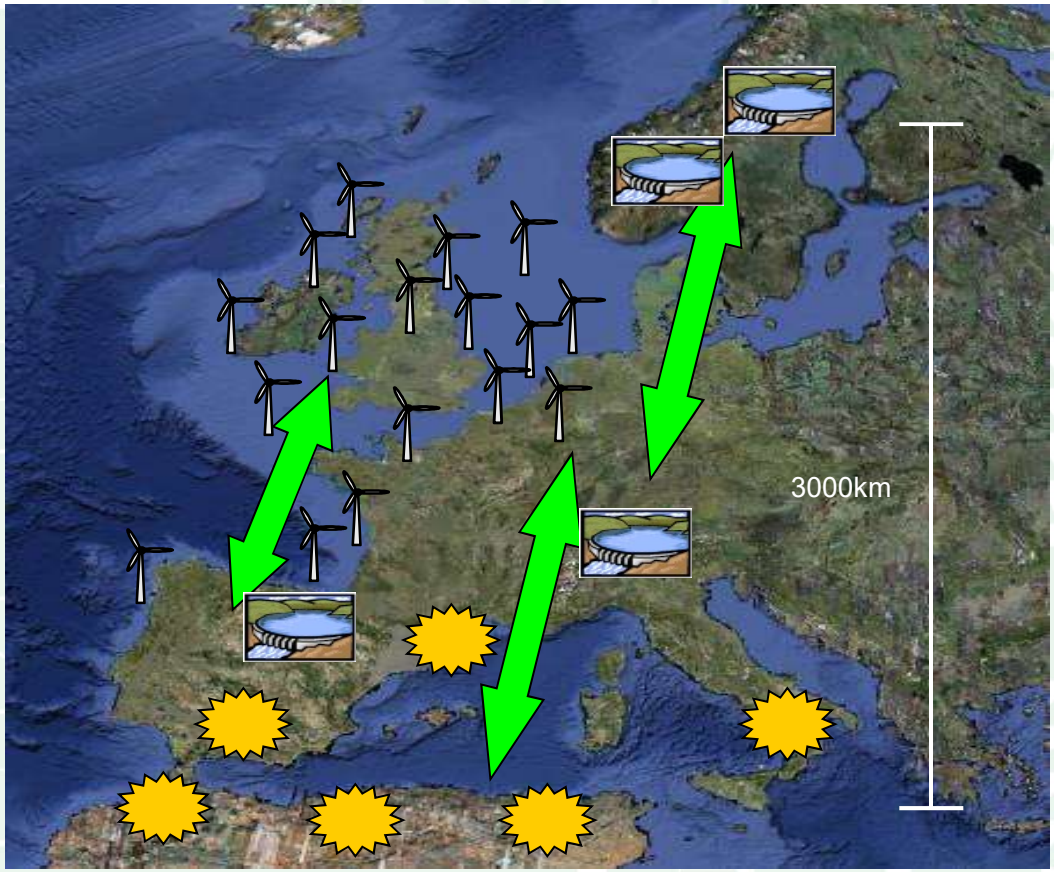
Source: NASA/DMSP/DNI with GE forecasted industry data, IEA, Bloomberg New Energy Finance, Platts, Deloitte

World Net Electricity Generation by source (trillion kWh)



Source: EIA, International Energy Outlook 2016

HVDC to re-distribute renewable energy



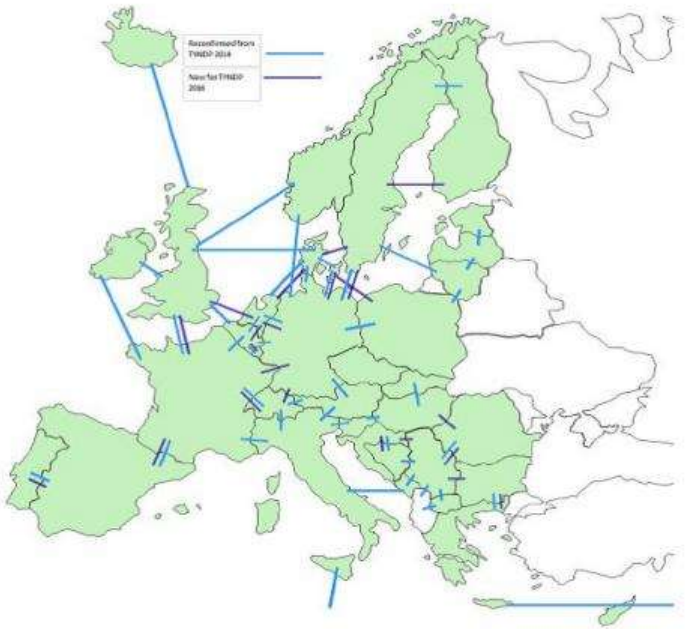
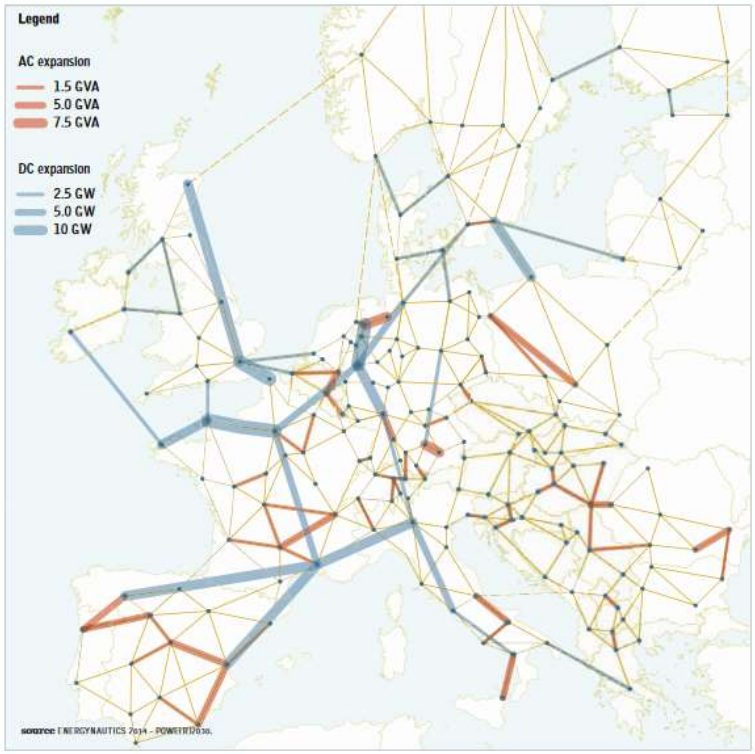


Figure 1-2 : Cross-border TYNDP 2016 project candidates

Source: *https://consultations.entsoe.eu/system-development/have-your-say-to-the-tyndp-2016-candidate-projects/*

Europe by 2030?

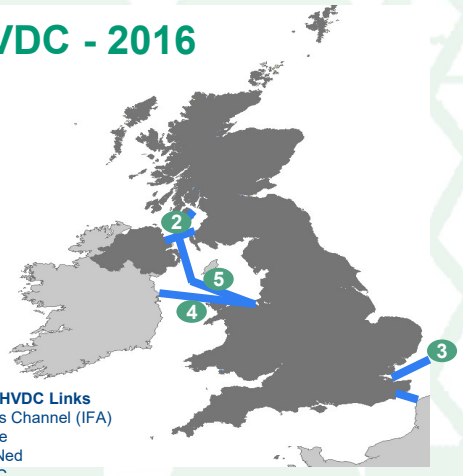
figure 2.15: extension map for energy [r]evolution scenario 2030



Source: https://www.greenpeace.de/files/publications/201402-power-grid-report.pdf

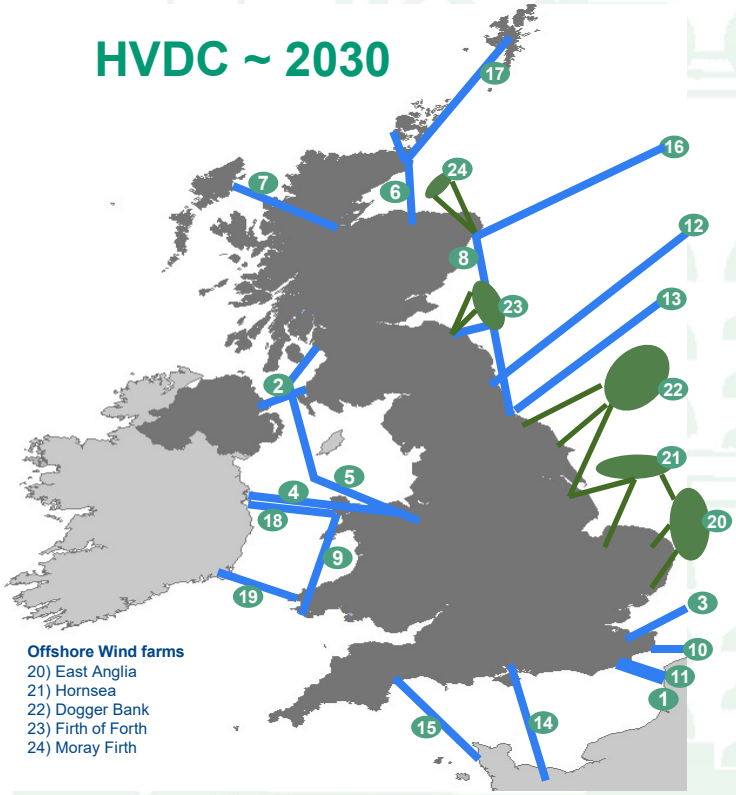
Great Britain's HVDC Connections

HVDC - 2016



Current HVDC Links
1) Cross Channel (IFA)
2) Moyle
3) BridNed
4) EWIC
5) Western Link

HVDC ~ 2030



Embedded HVDC
6) Caithness - Moray
7) Western Isles
8) Eastern Link
9) Wylfa – Pembroke

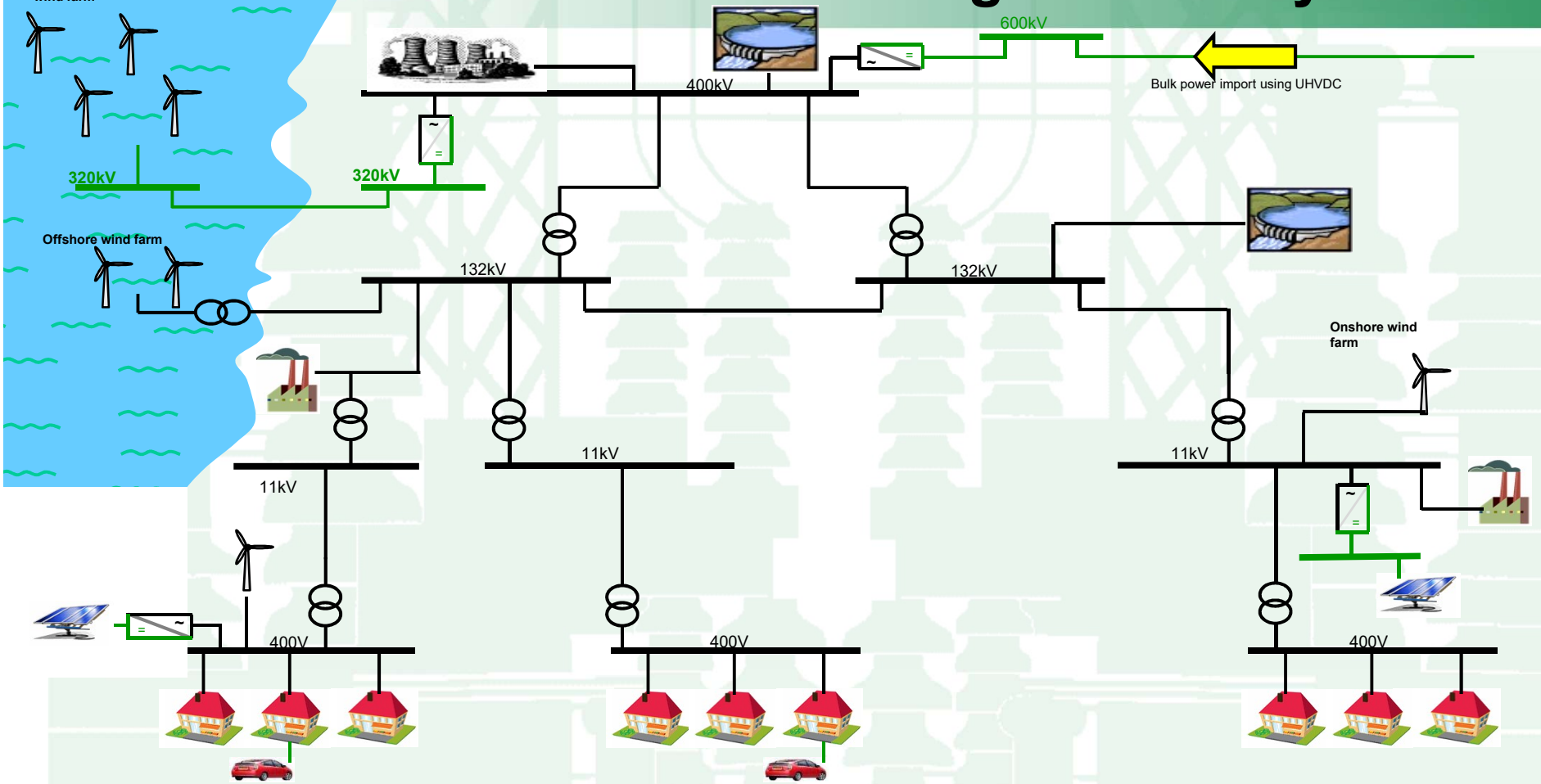
New Interconnectors
10) Nemo
11) ElecLink
12) NSN
13) Viking
14) IFA 2
15) FABLink
16) North Connect
17) Shetland
18) Greenwire North
19) Greenwire South

Offshore Wind farms
20) East Anglia
21) Hornsea
22) Dogger Bank
23) Firth of Forth
24) Moray Firth

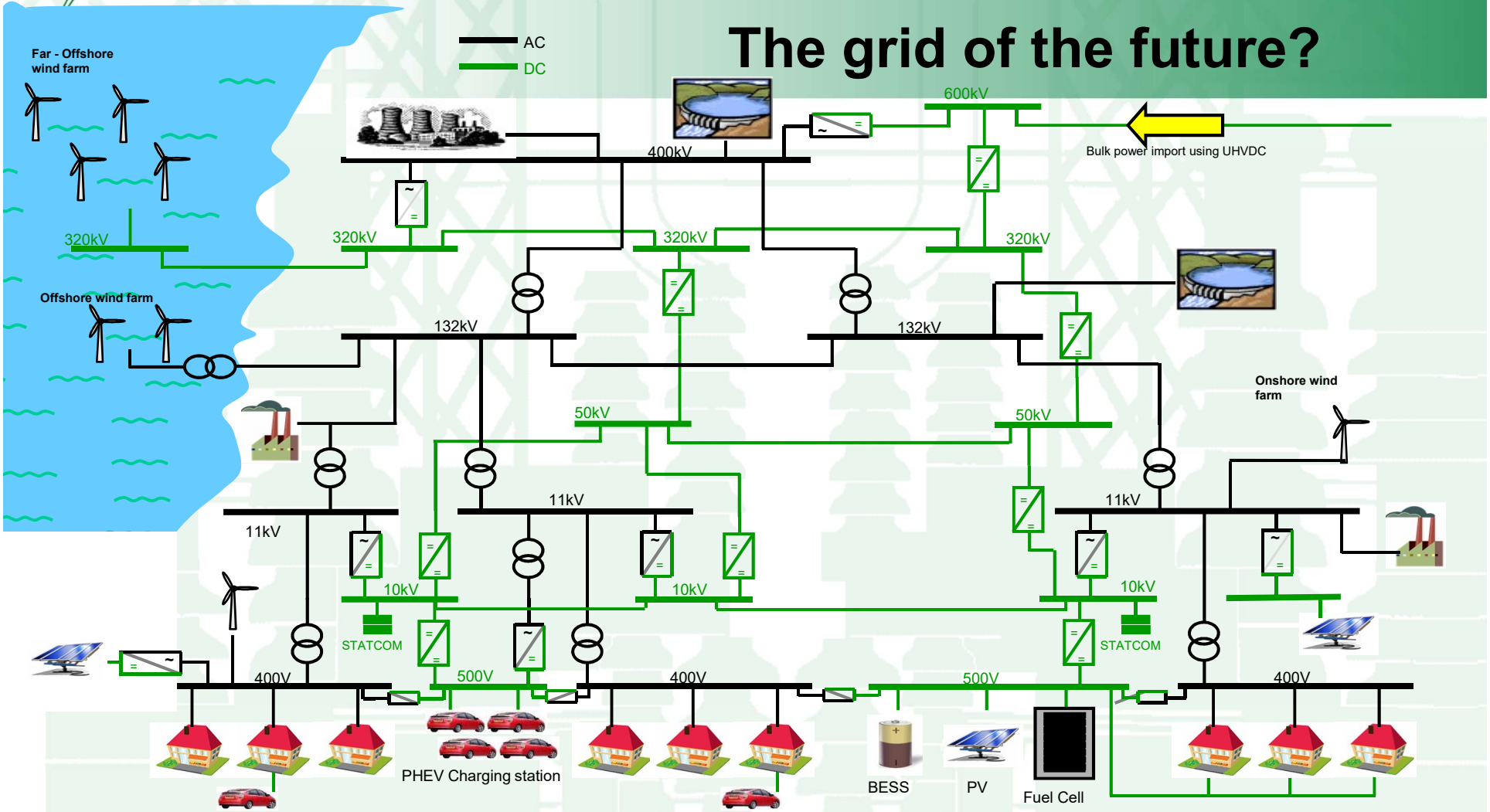
The National HVDC Centre

Based on National Grid's Electricity Ten Year Statement (2013):
http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Electricity-ten-year-statement/Current-statement/

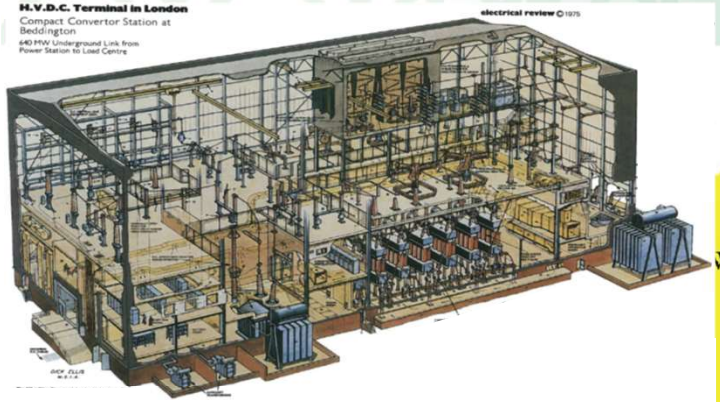
The grid of today

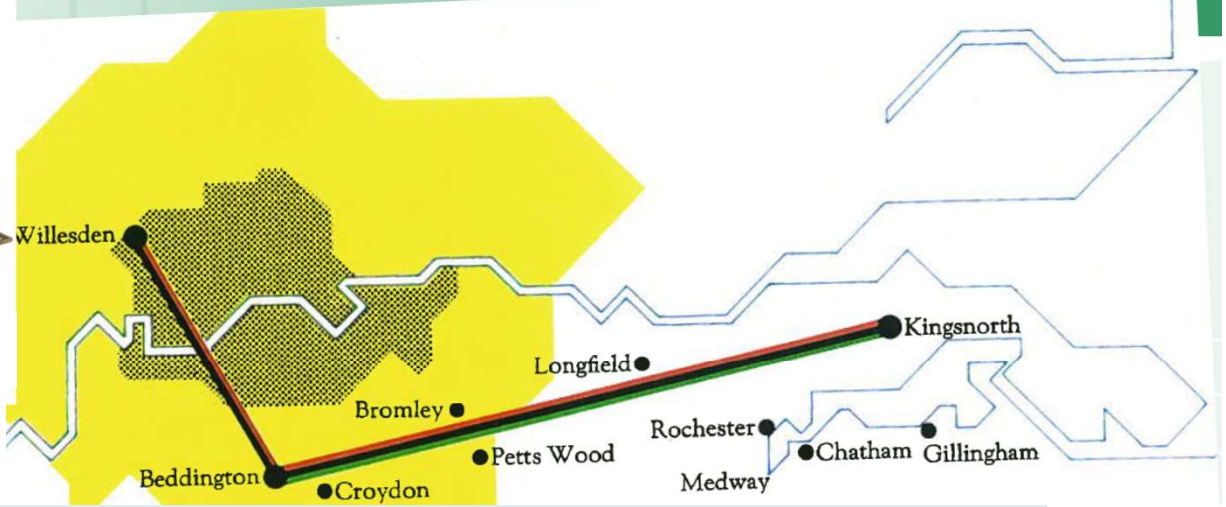


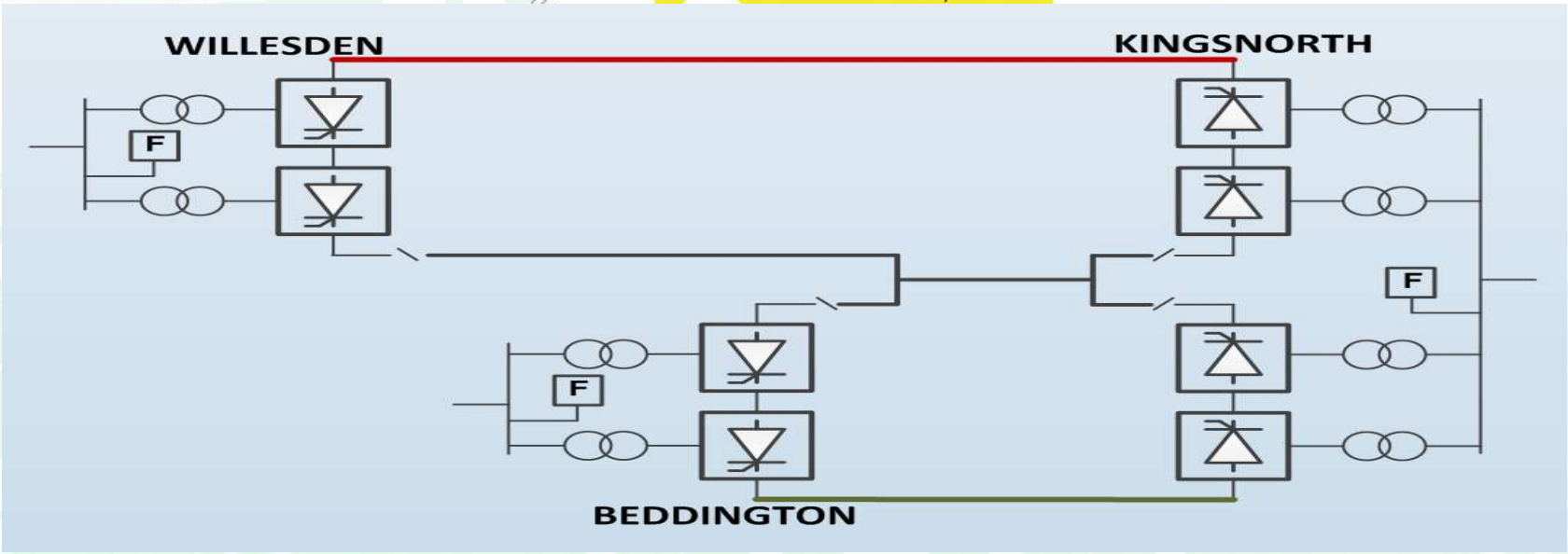
The grid of the future?



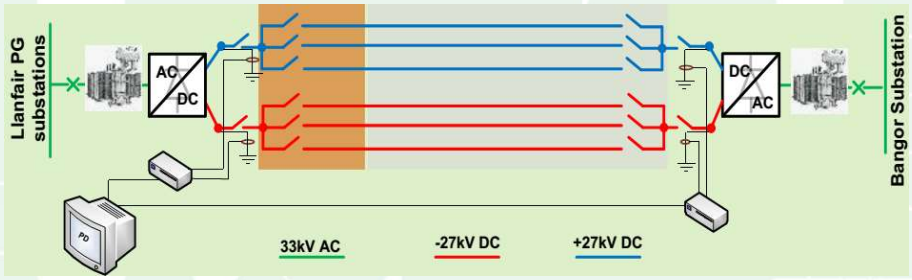
Historical Urban Infeed Schemes







ANGLE DC Project



Yu J, Smith K, Urizarbarrena M, MacLeod N, Byrans R, Moon A, "Initial designs for the ANGLE DC project; converting AC cable and overhead line into DC operation", IET, ACDC 2017, February, Manchester, UK

The need for rules

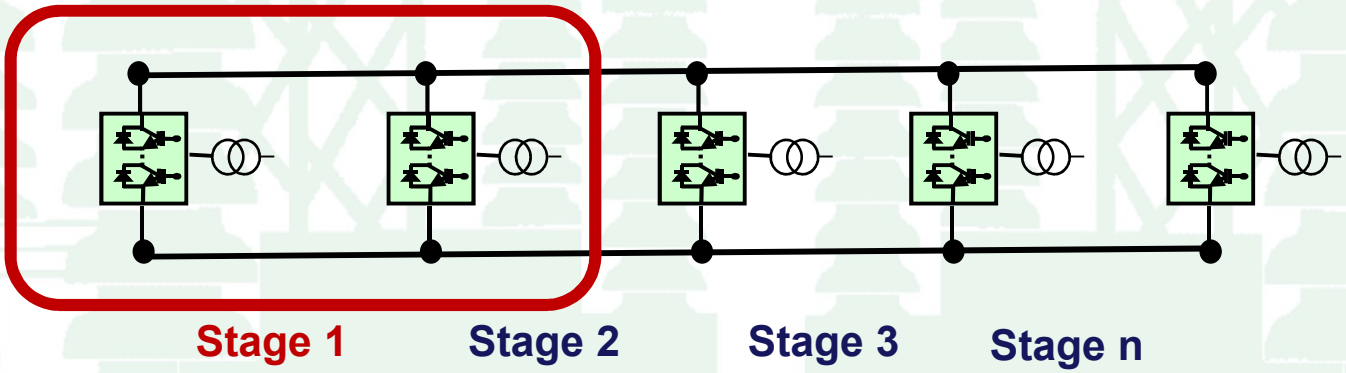
When you're on your own you can create your own rules

but…

when you're part of a team you need to agreed the rules

Image source ThinkStock

HVDC Multi-Terminal: thinking and planning ahead



HVDC Multi-Terminal: thinking and planning ahead

- DC Dispatch Centre;
- Additional hardware in Stage 1;
- Dynamic Performance studies for the entire HVDC Multi-terminal in the Stage 1 of the implementation
- First HVDC supplier to prepare a specification requirement with high level control strategy that will be implemented in the final stage of the HVDC multi-terminal
- Relevant Intellectual Property related to multi-terminal HVDC need to be available for the future supplier;
- Real Time Digital Simulation laboratory with replicas of the HVDC control is recommended;

HVDC Tomorrow

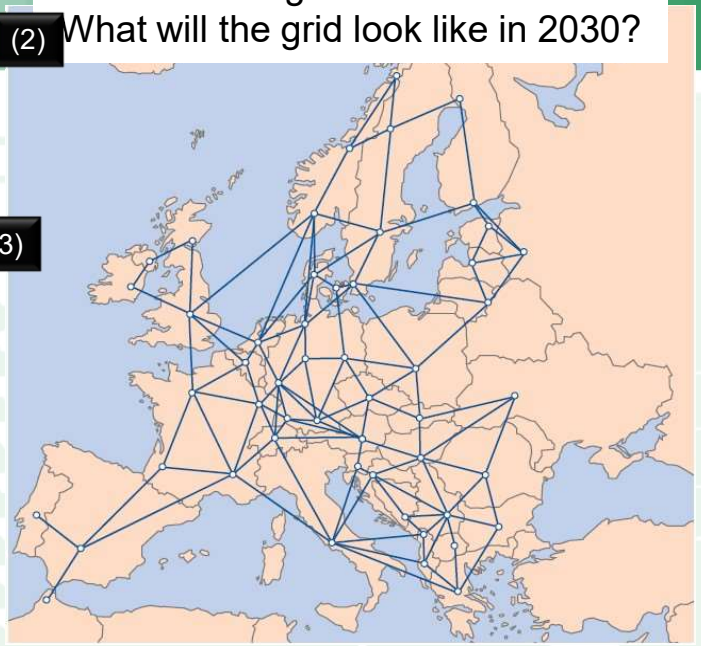
HVDC Grids – a Global Strategy

Asia Super Grid
36,000 km

(1)

In 2008, 8% of electrical energy was exchanged across borders.
What will the grid look like in 2030?

(2)



(3)

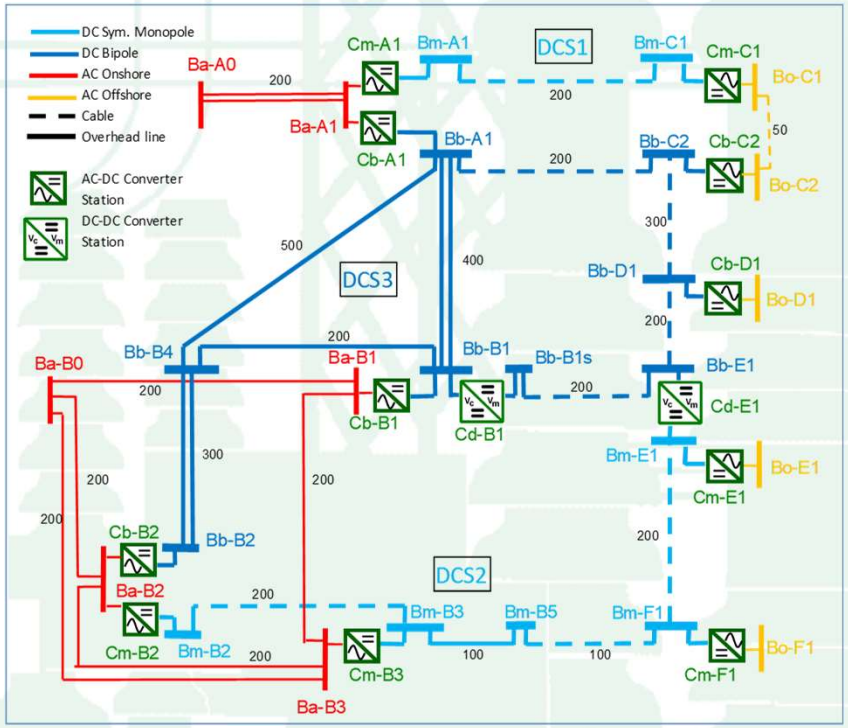
- Combined AC and DC grid control
- Optimal power flow
- WAM (Wide Area Monitoring) automatic response for system stability

Who manages HVDC Grid operation across borders?

(1) http://jref.or.jp/images/pdf/20110912_presentation_e.pdf
(2) http://www.egl.eu/content/dam/downloads/eglch/en/about/publications/EWK_Stromhandel_EN_Web.pdf
(3) "Offshore Electricity Grid Infrastructure in Europe; Techno-Economic assessment"
3E (coordinator), dena, EWEA, ForWind, IEO,NTUA, Senergy, SINTEF Final Report, October 2011

DEVELOPMENT OF DC GRIDS

- TB 533 HVDC Grid Feasibility Study, 2013
- AG 2 DC Grid Coordination
- TB 604 Guide to the development of models for HVDC converters in a HVDC grid, 2014
- TB 657 Guidelines for the preparation of “connection agreements” or “grid codes” for multi-terminal schemes and DC grids, 2016
- TB 684 Recommended voltages for HVDC grids, 2017
- TB 699 Control Methodologies for Direct Voltage and Power Flow in a Meshed HVDC Grid, 2017
- TB XXX Control and Protection of HVDC Grids
- TB 713 Designing HVDC Grids for optimal reliability and availability performance, 2018



The CIGRE B4 DC Grid Test System

http://b4.cigre.org/Publications/Documents-related-to-the-development-of-HVDC-Grids

Global Super-Grid?

THANK YOU

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