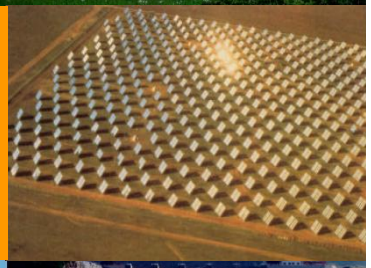






PLUS Technology for Large Scale Renewable Energy Integration



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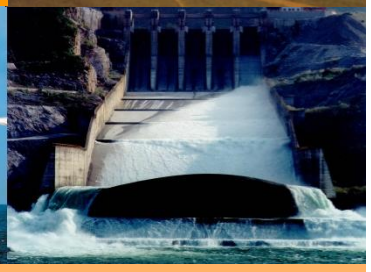

Energy Management

Vers. 8-4-00

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Overview

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1. Challenge of Grid Integration
2. HVDC PLUS® and SVC PLUS®
3. Project References
4. Conclusions

Impact on Grid Integration

- System Stability i.e. Rotor Angle Stability, Frequency Stability and Voltage Stability
- System Security e.g. Power Imbalance, Reserve Management and Voltage Control
- Power Quality e.g. Voltage Dips, Overvoltage, Harmonic, Flicker, Transients Overvoltage, and Voltage Unbalance

Integration of Wind and Solar System

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- System Stability
  - Power varies with Wind/Solar Resource
  - Require Reactive Power Control → SVC, STATCOM (SVC PLUS)
  - Trip of large Wind/Solar Farm is harm for Voltage Stability.
  - Sensitive Area connected to large Wind/Solar Farm can have Impact on Voltage/Frequency Stability.
  - No Contribution of System Inertia from Doubly-Fed Induction Generator and Fully Rated Converter Generator → Frequency Stability → required additional Control
- System Security
  - Wind and large Solar Farm must have Ability to Control Voltage and Frequency.
  - Fault Ride Through Capability
  - Require Reactive Power Control for proper Voltage Profile

➢ Power Quality

- Doubly-Fed Induction Generator, Fully Rated Converter Generator and Inverter System can be the Source of Harmonic, especially connect to weak Network.
- Voltage Fluctuation → Flicker, Voltage Imbalance.
- Voltage Dips cause the Disconnection of Wind/Solar Farm and consequently cause large Inrush Current during Recovery.

Germany: Voltage Profile at a 3-phase Fault

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System Configuration

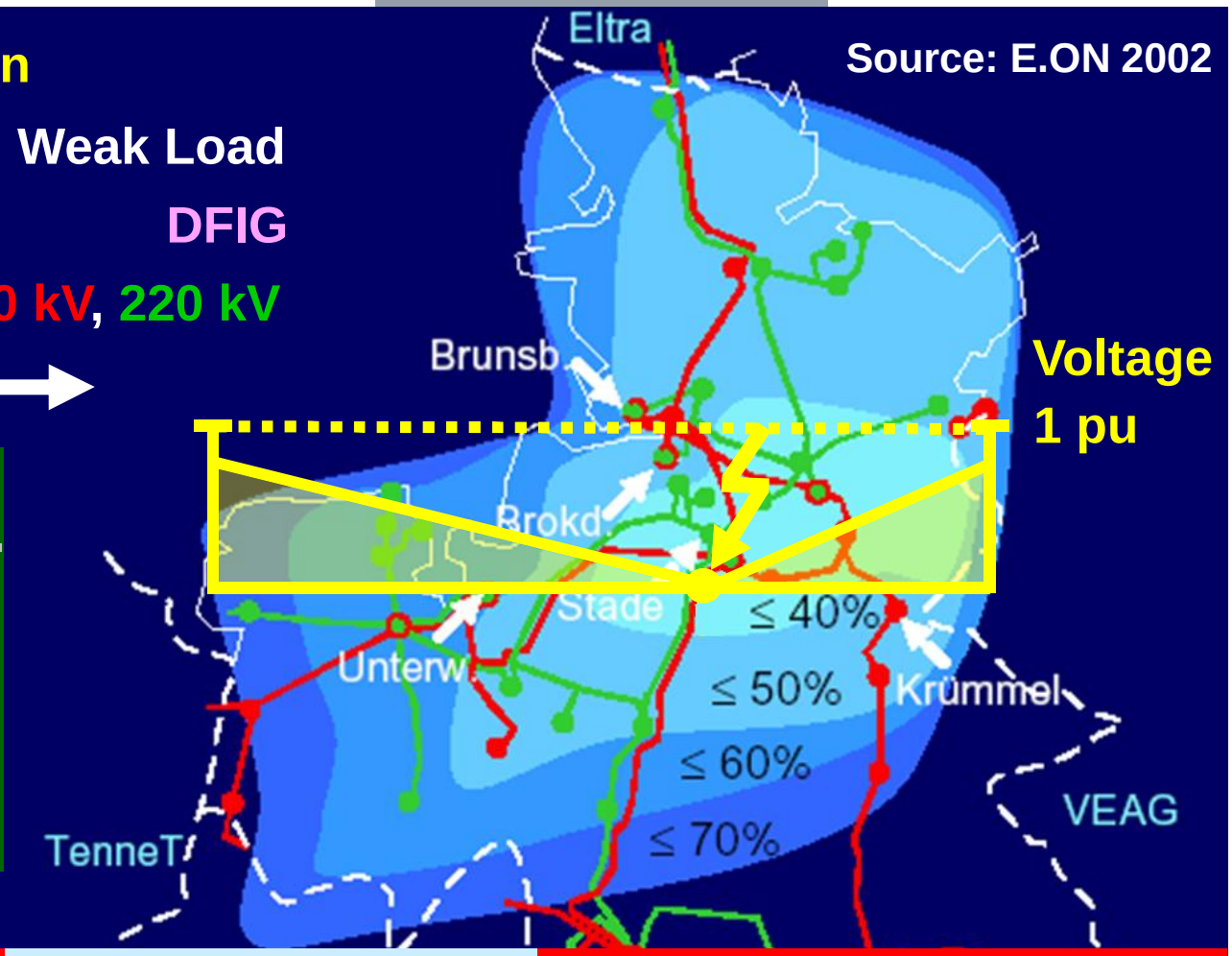
Network: 2001, Weak Load

Wind Generators: DFIG

Line Voltages: 400 kV, 220 kV

Power Stations: →

Voltage	Loss of WG
≤ 40 %	170 MW
≤ 50 %	1,130 MW
≤ 60 %	2,160 MW
≤ 70 %	2,700 MW



Outage of 2,700 MW Wind Power Generation →

Simulation Results: Voltage Support required

Voltage Collapse – and a large Blackout

PEBBs* for High Voltage: HVDC & SVC PLUS

Future Molding Technologies,

Innovation Meets Experience

focused on Green Energy and CO_2 Reduction

The Evolution of VSC Technology

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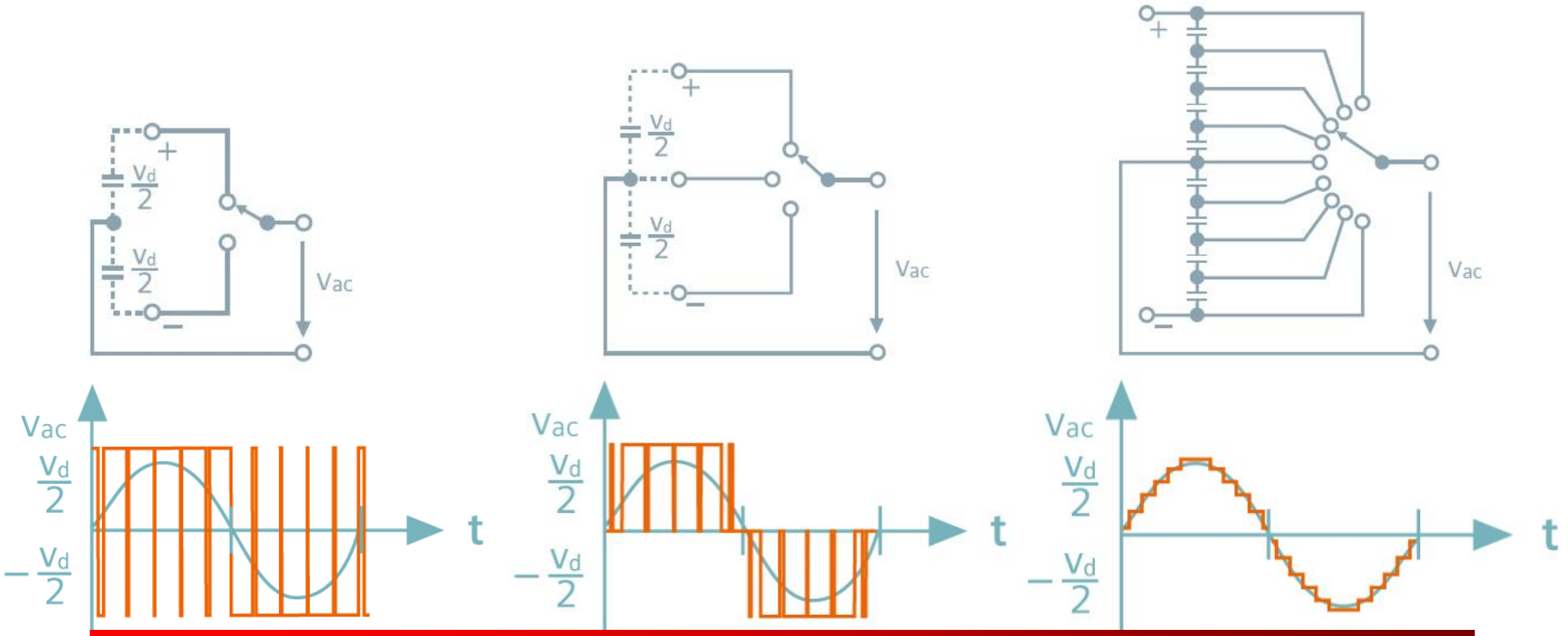
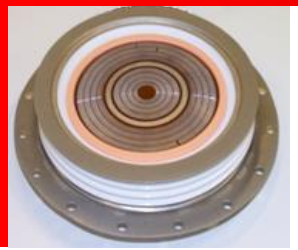
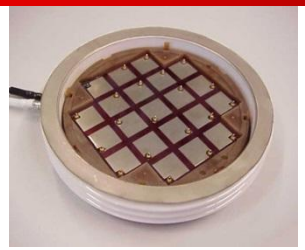
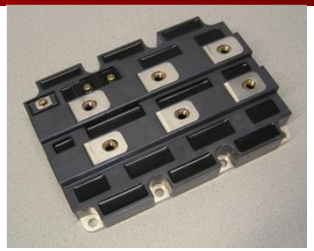
Topologies:	Two-Level	Three-Level	Multilevel



	GTO / IGCT	IGBT in PP	IGBT Module
Power Electronic Devices:			

General Features of SVC PLUS

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Grid Access for Wind Farms and Renewables

Elimination of Voltage Fluctuations and Flicker

High dynamic Performance

Low Space Requirements

VSC Technology makes it feasible

SVC PLUS with MMC** offers additional Benefits

Virtually Harmonic-free and lower Losses

Significant Space Savings – quite easy to relocate

*** VSC: Voltage-Sourced Converter** **** MMC: Modular Multilevel Converter**

Grid Access of Green Energy with SVC PLUS: Greater Gabbard, UK – 3 SVC PLUS Systems …

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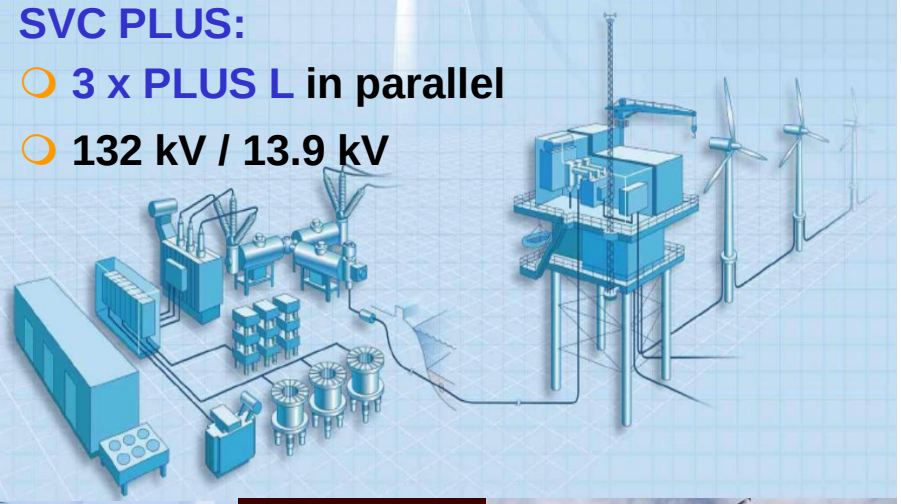
Norwich

Sizewell Village
132 kV

SVC PLUS:
- 3 x PLUS L in parallel
- 132 kV / 13.9 kV



2010

Ipswich

SVC PLUS:
- 4 x PLUS L in parallel
- 150 kV / 13.9 kV

2011

Greater Gabbard
500 MW
140 x 3.6 MW

… and London Array

World's largest Offshore Wind Farm

630 MW & Upgrade up to 1 GW

London

Grid Access of Green Energy with SVC PLUS: Greater Gabbard, UK – Leiston Onshore Substation

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General Features of VSC* HVDC

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Grid Access for weak AC Networks

Independent Control of Active and Reactive Power

Supply of passive Networks and Black-Start Capability

Multiterminal easier with Reversion of Current Polarity

High dynamic Performance

Low Space Requirements

VSC Technology makes it feasible

HVDC PLUS with MMC offers additional Benefits**

*** VSC: Voltage-Sourced Converter** **** MMC: Modular Multilevel Converter**

HVDC PLUS INELFE: World's first VSC Multilevel HVDC with 2 x 1,000 MW

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INELFE

- Customer:
  RTE and REE
- World's 1st VSC HVDC with 2 x 1,000 MW – each @ V_{DC} = +/- 320 kV
  Cable: XLPE, 65 km

- Power Exchange &
- Increase in Stability
- Sharing of Reserve Capacity
- No Increase in Short-Circuit Power

Conclusions

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- **HVDC – High-Voltage DC Transmission: It makes P flow**
- **FACTS – Flexible AC Transmission Systems: Support of Power Flow**
- **HVDC PLUS and SVC PLUS using Modular Multilevel Converter (MMC) provide the feasibility to connect a grid because of:**
  - **High dynamic performance**
  - **Compact modular design, less space requirement and Harmonic-free (High Power Quality Product)**
  - **Independently control active and reactive power**
  - **Supply passive network and black-start capability**
  - **Grid access for weak AC networks**

Contact page

Thank you for your attention!

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