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Protection/Technical Issues when Implementing Renewables and Alternatives

Wednesday, 3rd August 2022 | Technical Topic Webinar

Presented by Professor Akhtar Kalam, EIT Academic Board Chairman

CRICOS Provider Number: 03567C | Higher Education Provider Number: 14008 | RTO Provider Number: 51971

Common Questions/FAQs

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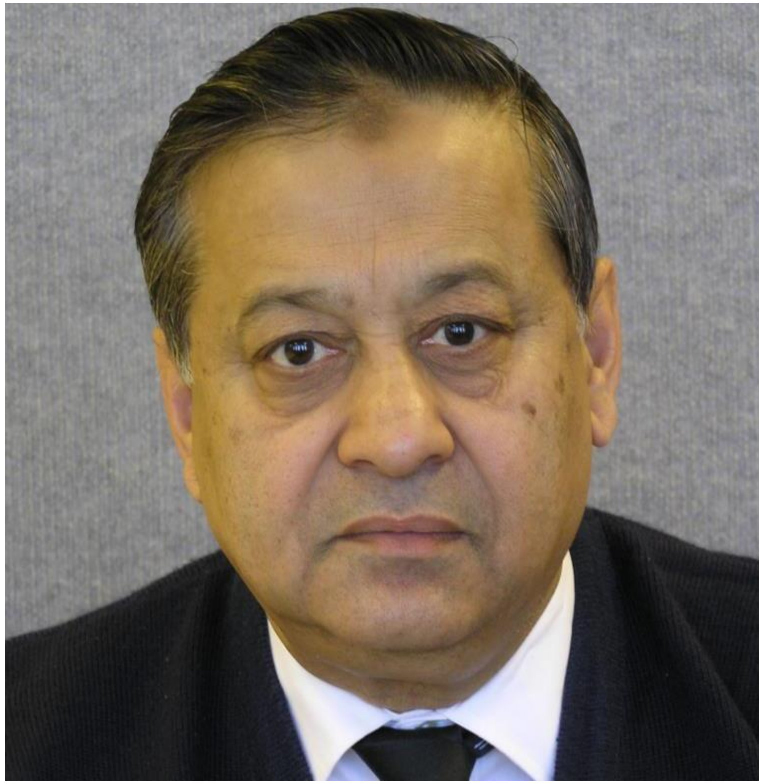
Agenda

1	Welcome and Introduction
2	Network Responsibilities
3	Embedded generation
4	Why Distributed Generation?
5	Some of the issues
6	International and Examples of DG Activities
7	Conclusion and Q&A

Introduction - Presenter



“My vision is to provide exciting higher education science and engineering courses, research, consultancy and collaborate in development work of the industry and communities within Australia and beyond.”

Professor Akhtar Kalam JP

BSc, BScEng, MS, PhD, FIET, CEng, FAIE, FIEAust, CPEng, PEV, NER, APEC Engineer, IntPE(Aus), MCIGRE, Life Senior Member of IEEE

Head of External Engagement and Professor at Victoria University
Chair and Deputy Chair of TCA and EIT Academic Board, respectively
Director of Al-Kalam Educational Solutions
Editor-in-Chief of AJEEE

- Distinguished Professor/Adjunct Faculty in Australia, India, Malaysia and Oman
- Published over 610 publications in his area of expertise and written over 29 books in the area
- Supervised 49 postgraduate research students to graduation consisting of 38 PhDs and 11 MEng. Currently, 12 postgraduate research students being supervised (one MEng student)
- Public, University and Motivational Lecturer
- Consultant for the electricity supply industries
- Assisted in change management plans to Universities and higher education sector.

Education

- The University of Bath, Bath, UK, PhD, Electrical Engineering
- The University of Oklahoma, Norman, USA, MS, Electrical Engineering
- Aligarh Muslim University, Aligarh, India, BScEng, Electrical Engineering
- St Xavier's College, Calcutta, India, Applied Science.

Professional Society Activities

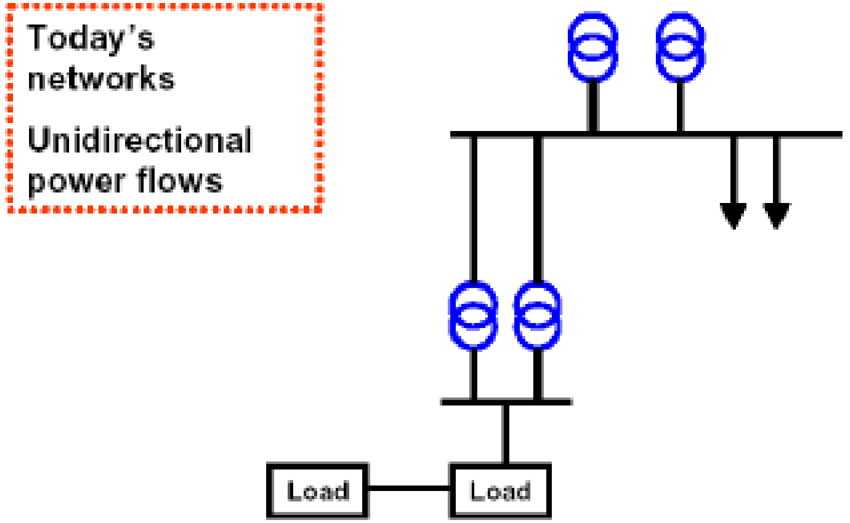
- Australian Institute of Energy – Fellow
- Engineers Australia – Fellow
- The Institution of Engineers and Technology, UK – Fellow
- The Institution of Electrical and Electronic Engineers, USA –Life Senior Member.

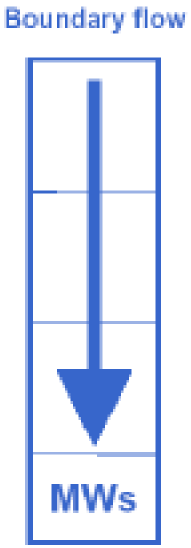
Network Responsibility

Principal Objective for Networks

- Adequate capacity of network to supply load
- Adequate level of redundancy (security standards)
- Adequate safety, fault rating of components and ability to protect
- Adequate power quality (voltage, frequency, harmonics, etc)
- Adequate reliability of network

Impact of EG on Network

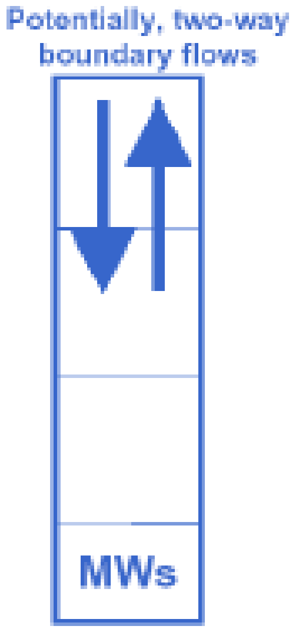




Previously:

- only source from transmission system - vertically operated - generation / transmission / distribution / utilisation

Impact of EG on Network



With distributed generation:

- Sources can be embedded anywhere in network
- Wide variety of types and characteristics of distributed generation
- Wide variety of impacts on network
- Fundamental changes to philosophy of network
- Many issues not well understood
- Impact on planning, operations and safety

Embedded Generation Benefits

- Can potentially result in deferment of expenditure on the network
- Reduces network losses
- Can improve local voltage level
- Can have a positive environmental advantage
  - Wind turbines utilise natural wind energy
  - Solar cells utilise available sunlight
- Combined heat and power improves overall energy efficiency
- Can assist with achieving Greenhouse targets by displacing coal, oil or gas electricity generation

Embedded Generation Costs

- Additional assets need to be installed
- Operational and safety issues
- Maintenance

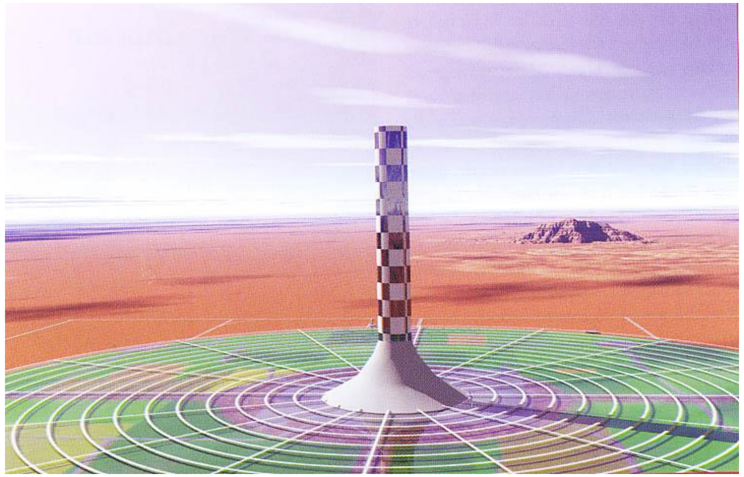
Impact of Renewables

- Renewables the major driver of DG
- Some see renewables as providing an increasing proportion of energy of world energy resource
- Demand for energy strong in developing countries
- Renewable energy sources have improved in performance and cost
- In past decade growth of renewables greatest in six countries - China, Denmark, Germany, India, Spain and the US
- These countries represent 80% of photovoltaic and wind energy capacity

Renewables

- Wind / Seawind
- Photovoltaics
- Solar Thermal
- Hydro
- Geothermal
- Methane extraction (landfill/ coal seam)
- Biomass
- Marine
- Cogeneration (electricity + heat/steam)
- Others





Should DG be challenged?

- Can poor economy of scale but local production offset large scale base power?
- Are network losses significant in considering local generation?
- To date all renewables require incentive structures for financial viability
- Should there be greater focus on end-use efficiency?
- Should there be a new paradigm
- Will carbon taxes be introduced?
- If so, what impact would they have – nuclear?

European Energy Target

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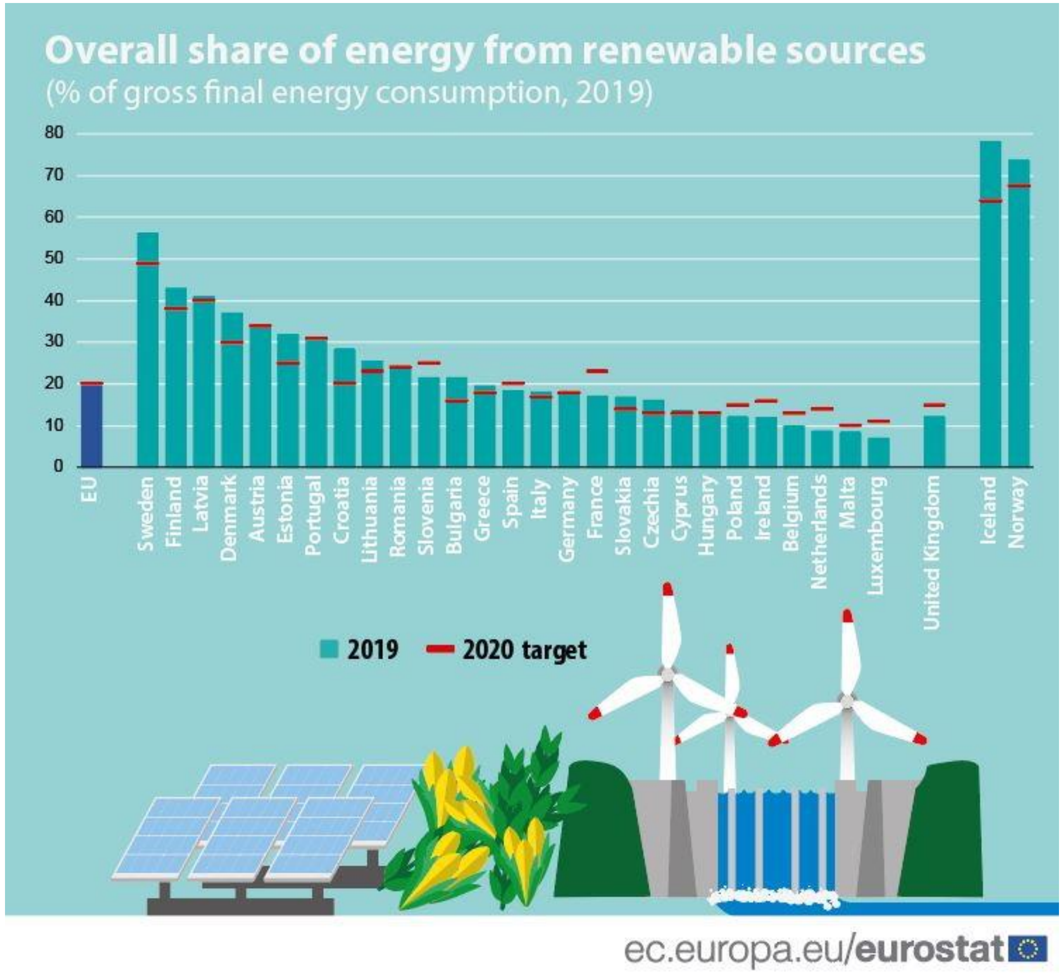
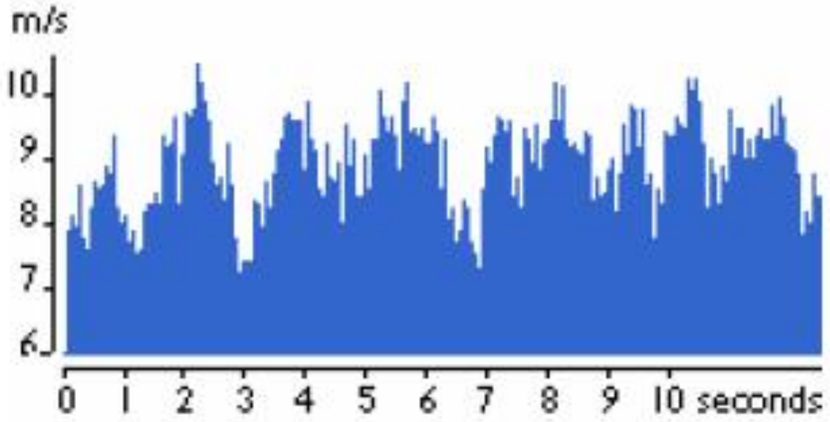
Building on the 20% target for 2020, the recast Renewable Energy Directive 2018/2001/EU established a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a possible upwards revision by 2023.



Dominance of Wind

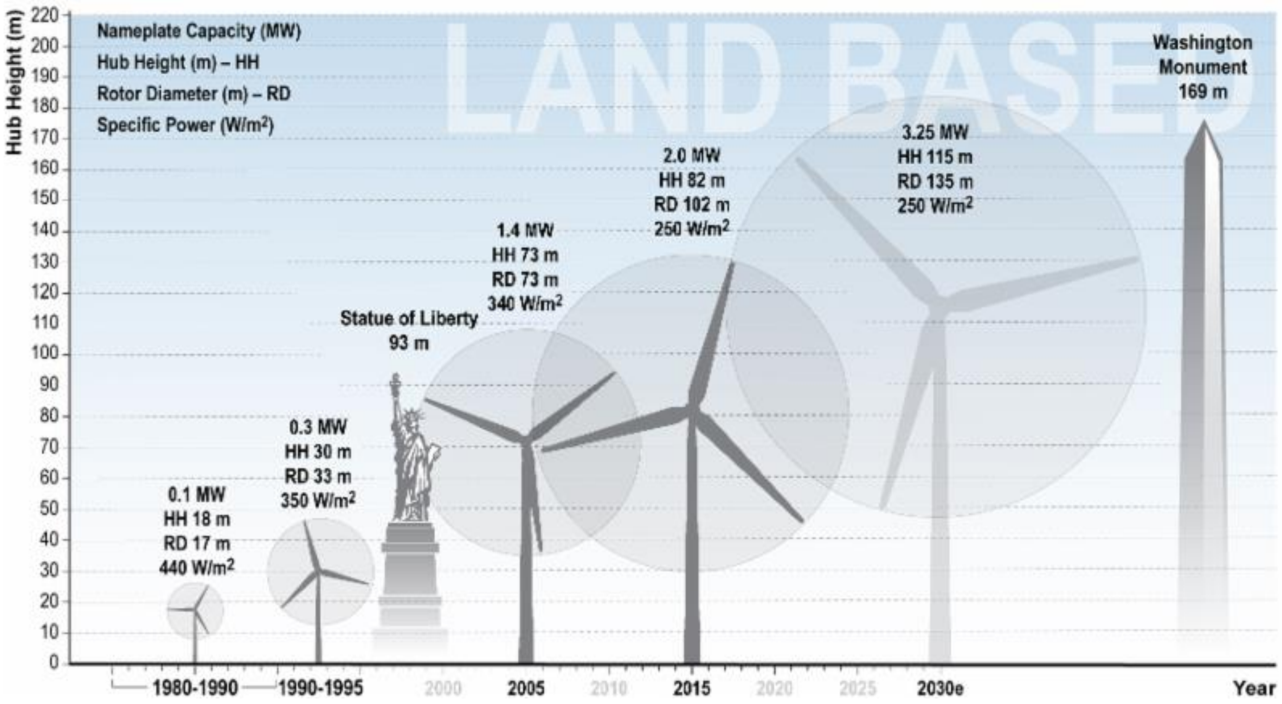
Renewable electric energy is mainly wind energy which by essence is a fluctuating power source.

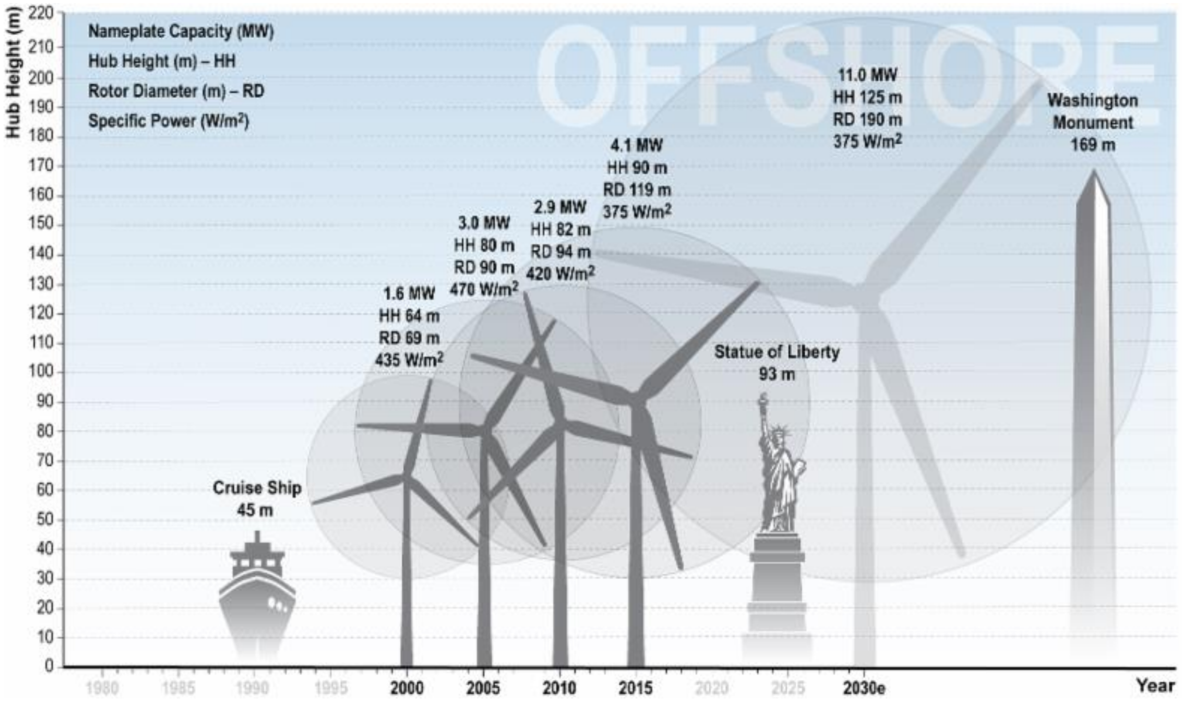


Dominance of Wind

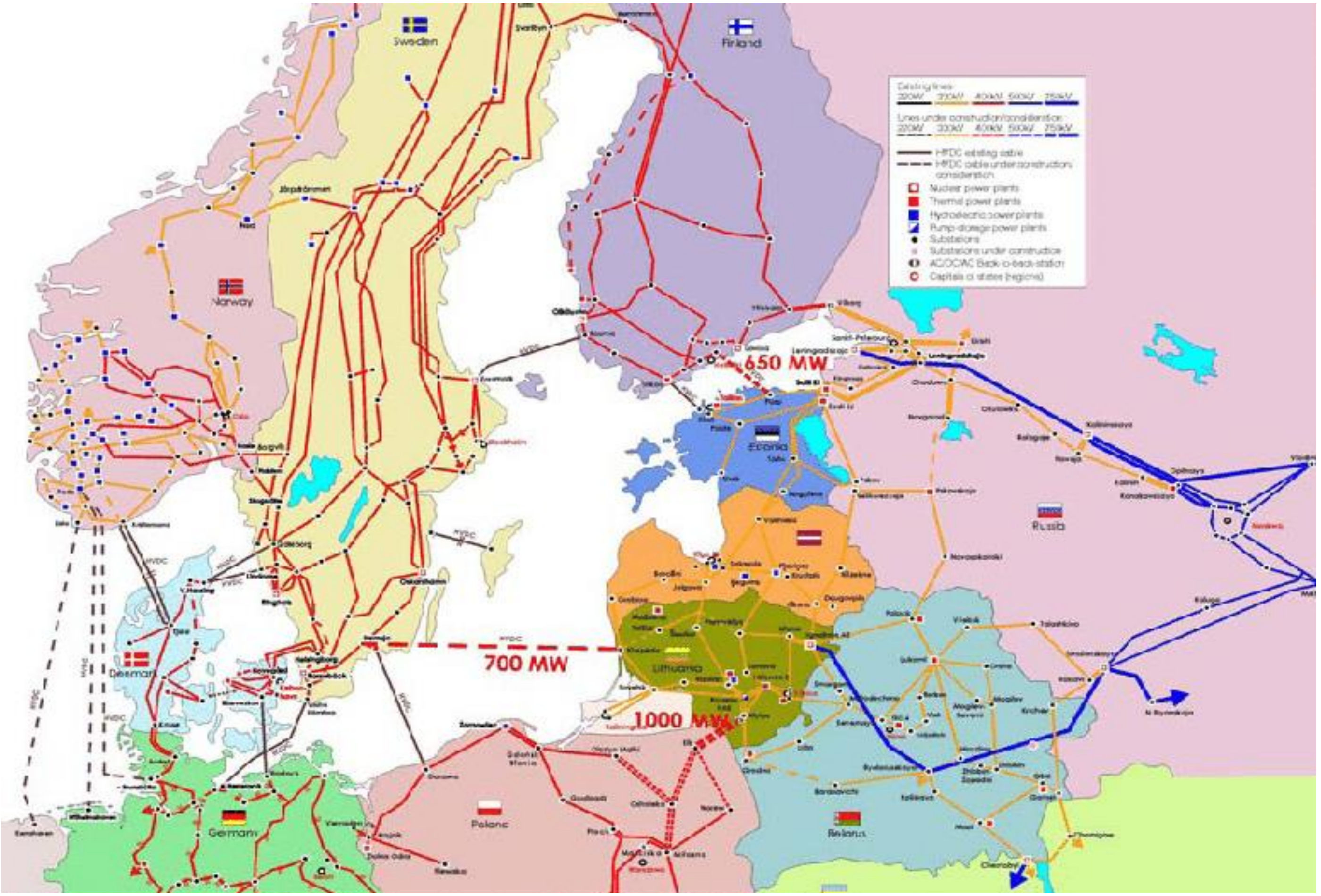
- By 2030, the energy generated or stored and dispatched by solar and wind technologies will undercut electricity generated by existing coal and gas plants almost everywhere.

Wind Turbines – They are getting bigger





RES Integration – State of off-shore wind project in Baltic Sea



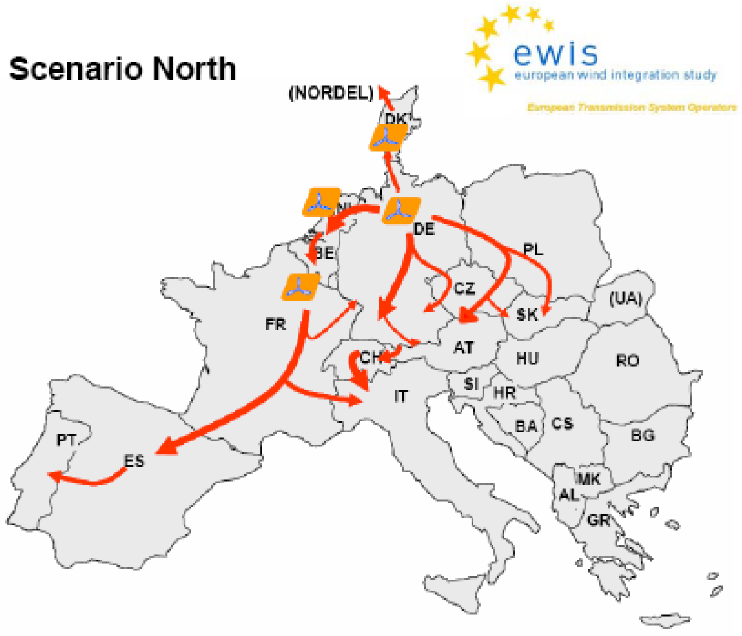
In September 2020 eight Baltic countries – Poland, Germany, Denmark, Sweden, Finland, Lithuania, Estonia and Latvia – signed a joint declaration with the Commission to accelerate the build-out of new offshore wind in the region. And the North Seas Energy Cooperation should help them build on the successes of offshore wind in the North Sea, as well as the UK.

Impact on network development needs in the short term

❖ **at the European System scale**

- Originates large load flows which affect neighbouring transmission systems
- Creates grid congestions and bottlenecks at European level
- Fluctuations reduce available cross border trading capacities

Reinforcement of interconnections needed!

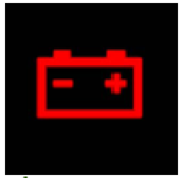


These consequences should be analysed from the point of view of :

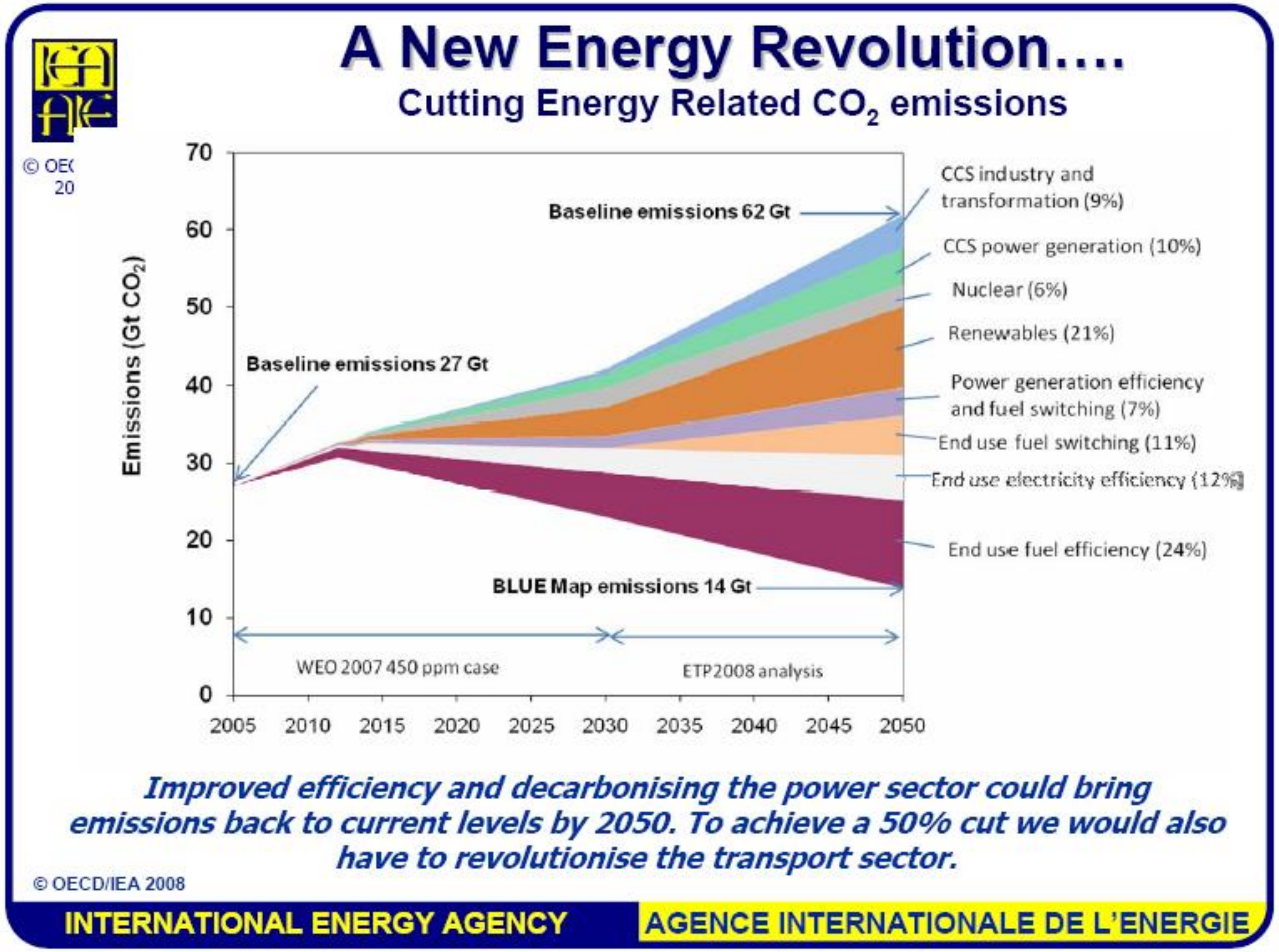
① The development of transmission and distribution systems

② Their impact on the power system operation and control

③ The consequence on the price of electricity for the end users (taking into account the external effects of environment)



④ The need for new storage electric devices (advanced or conventional).


A New Energy Revolution….
Cutting Energy Related CO2 emissions
© OECD/IEA 20
Emissions (Gt CO2)
70
60
50
40
30
20
10
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Baseline emissions 62 Gt
Baseline emissions 27 Gt
BLUE Map emissions 14 Gt
WEO 2007 450 ppm case
ETP2008 analysis
CCS industry and transformation (9%)
CCS power generation (10%)
Nuclear (6%)
Renewables (21%)
Power generation efficiency and fuel switching (7%)
End use fuel switching (11%)
End use electricity efficiency (12%)
End use fuel efficiency (24%)
Improved efficiency and decarbonising the power sector could bring emissions back to current levels by 2050. To achieve a 50% cut we would also have to revolutionise the transport sector.
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INTERNATIONAL ENERGY AGENCY
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Emissions Reductions From Wind Generation

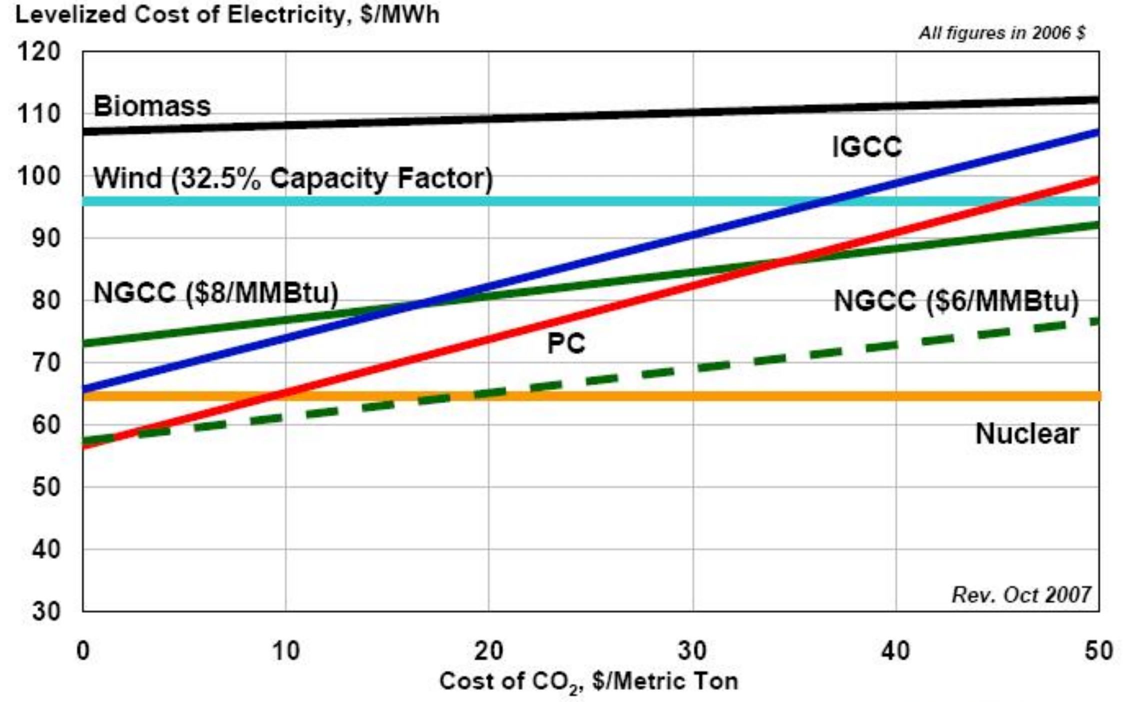
Emission	Annual Reduction per MW Wind
CO_2 [a]	2,050 ton/year
So_x [a]	1.4 ton/year
NO_x [a]	0.7 ton/year
Mercury [b]	0.2 pound/year

(a) Based on 5,000 MW of wind, where wind displaces 80% gas and 20% coal. "Analysis of Transmission Alternatives for Competitive Renewable Energy Zones in Texas," (ERCOT 2006A).

(b) Department of Energy and Energy Information Administration.

Source: ISO/RTO Council, October 2007

Comparative Levelized Costs of Electricity 2010–2015



Source: EPRI Energy Technology Assessment Center

CWG/9749P

Impact on network development needs in the short term

- Wind power is largely concentrated in some regions which were beforehand "electrical deserts"
  - need of new links for connection to the main grid
- Wind power substitutes thermal units located closer to the loads
  - changes of usual flows
  - need of reinforcements of main grid
    - the German example

❖ Technical challenges

- Define basic technical principles
  - respective part of AC and DC
  - feasibility of DC multi-terminal links
  - evolution towards DC networks
  - flexibility
  - reliability
  - control….
- Consequences on on-shore grid development and operation
  - Concentrated large intermittent infeeds
  - Coordinated plan at European level ?

Challenges for Europe

- Onshore and offshore wind power development, in addition to renewal of thermal generation fleets, let the European grid enter into a new era
- Strong TSO coordination is a prerequisite to develop an adequate European grid
- Speeding up the approval procedures for new grid infrastructure is a condition to meet the energy policy objectives
- However innovative solutions including under-grounding will be required by external stakeholders
- Offshore grids open new frontiers for the electricity industry…
- …but a lot of issues still need to be examined (regulatory, financial..)

Storage

Background and justification

- The new electricity generation context
  - Increasing the penetration of renewable energy resources, mainly wind and solar, as well as hydro power and biomass
- The issues
  - Managing the intermittency of wind and solar energy, so that these resources can be incorporated into to the base load generation
  - Managing large load fluctuations – supplying peak consumption
- The solution
  - Storing energy from renewable sources and from the grid in a form recoverable as electrical energy when required
- The constraints
  - Technologies – equipment availability and life cycle
  - Capital and operating costs (losses, maintenance and others)

Storage

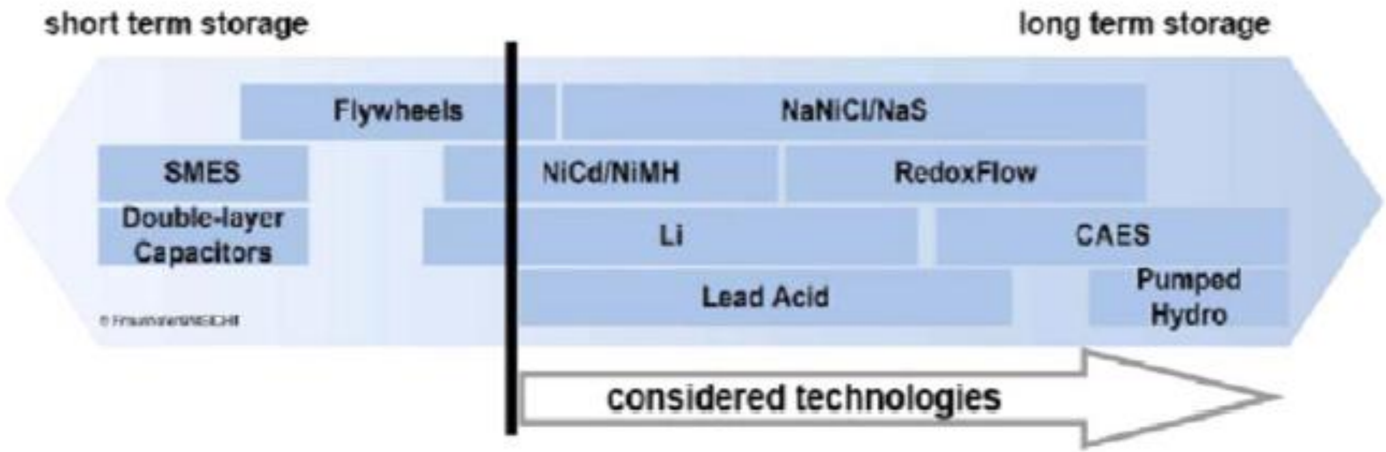
Benefits of storage

- Accommodating intermittent generation - allows it to operate at peak power and efficiency by storing surpluses
- Ability to dispatch energy during times of peak demand – peak load management
- Ability to supply peak demand locally and reduce transmission line demand (avoid transmission line congestion)
- Ability to provide voltage support, voltage regulation (voltage sag compensation, flicker) and power factor correction
- Ability to provide other ancillary services – frequency regulation, black start, reactive power
- Possibility of islanded operation
- Ability to perform arbitrage on electricity prices – electricity markets

Storage technologies – general considerations

- Electrical storage
  - Electrolyte type batteries – Lead Acid, Lithium Ion, etc
  - Flow batteries – Vanadium Redox, Zinc Bromide, etc
  - Capacitors and supercapacitors
- Magnetic storage
  - Superconducting magnetic energy storage (SMES)
- Mechanical storage
  - Flywheels
  - Compressed air
  - Pumped hydro storage

Storage technologies – operating time frames



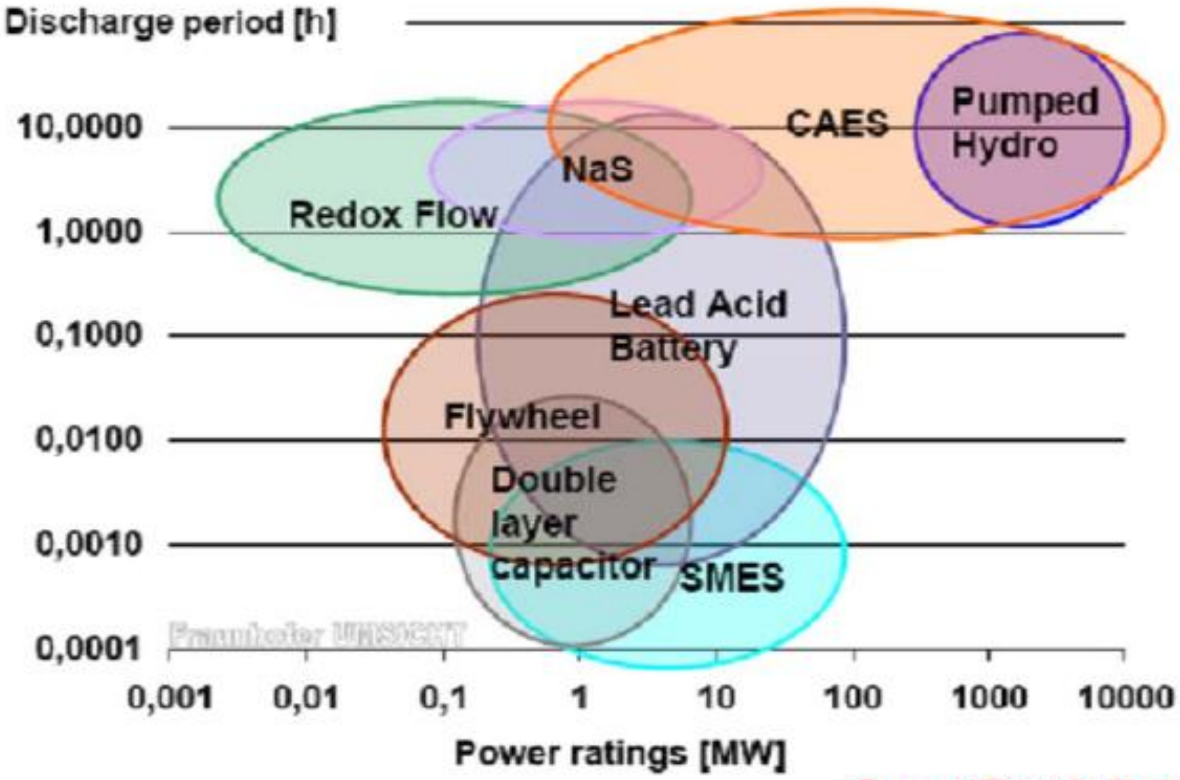
Worldwide survey on storage technologies:

- only long term storage
- technical (and economical) data available
- capacity > 100 kW_{el}

approx 500 projects taken into account

<u>Sources:</u> Internal Study / EPRI Handbook, USA 2003 / DTI Review, UK, 2004 / Gonzalez, Ireland, 2004

Storage technologies – energy and power ratings



Source: Fraunhofer UMSIGHT

Storage deployment – limitations and opportunities

- Deployment limitations – batteries and other technologies
  - Need to reduce costs - expensive
  - Life cycle and asset management
  - Life cycle for severe environments – to be determined
- Building a business case
  - Storing vs direct use of electric energy
  - Losses – complete cycle from storage to retrieval
  - Amortizing capital and operating costs – capitalizing losses
  - Current electricity costs – competing with low production costs in large scale generating plants
- Possible business opportunities
  - Remote location and new developments (no electrical infrastructure)
  - New installations requiring high power quality and reliability

Hydrogen storage – applications to remote locations

- Hydrogen production from wind energy
  - More than 50% of the wind energy in a given configuration may be wasted (dumped) as it can not be absorbed into the isolated diesel grid
  - Excess energy can be used for hydrogen production
  - Hydrogen fuel contributes to the firm power available to the community
- Hydrogen as an energy source – advantages
  - Emission free combustion in internal combustion engine (and fuel cells)
  - Transportable renewable energy source
- Hydrogen as an energy source – issues
  - Overall process (generation-storage-consumption) efficiency
  - Effective integration of multiple energy sources
  - Availability of the technology and commercialization issues

Wind and hydro power – integration

- Issues – power balancing
  - Wind penetration – limits (below 10 %, and above)
  - Nature of the hydro reservoirs – storage capability – yearly or multi-year reservoirs – pumped storage
- Wind power integration issues
  - Integration costs – transmission upgrade
  - Integration costs – power balancing
- Impact of wind integration
  - Impact on generation dispatch - mitigation by means of precise wind forecasting methods
  - Impact on real time and day ahead market operation
- Operational constraints
  - Impact on hydro plant efficiency and life

Technical Issues for DG/EG

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- Maturity of technology
- Network Design
- Network Operation
- Electrical Protection
- Variety of technologies
- Connection costs
- Role of Information Communication Telecoms
- Network Capacity
- Power Quality
- Reactive Power and Voltage Control
  - Impact of weak systems
- Reliability
- Impact/ benefit to security
- Islanding
- Safety

Maturity of Technology

- Technology still developing
- “New” and improved technologies
- Power electronics key to most technologies
- Still searching for “magic bullet”
- Many applications still looking for storage
- Super capacitor provides new dimension

Network Design

- Capacity of network to accept connection
- Short circuit capacity
  - Increase with synchronous machines
  - Decrease with Power electronics
- Performance of switchgear
- Power flow directions

Network Operation

- Need to know location of EG
- Ride through capability during faults
- Becoming big issue with higher penetration
- Synchronisation/ out of phase condition

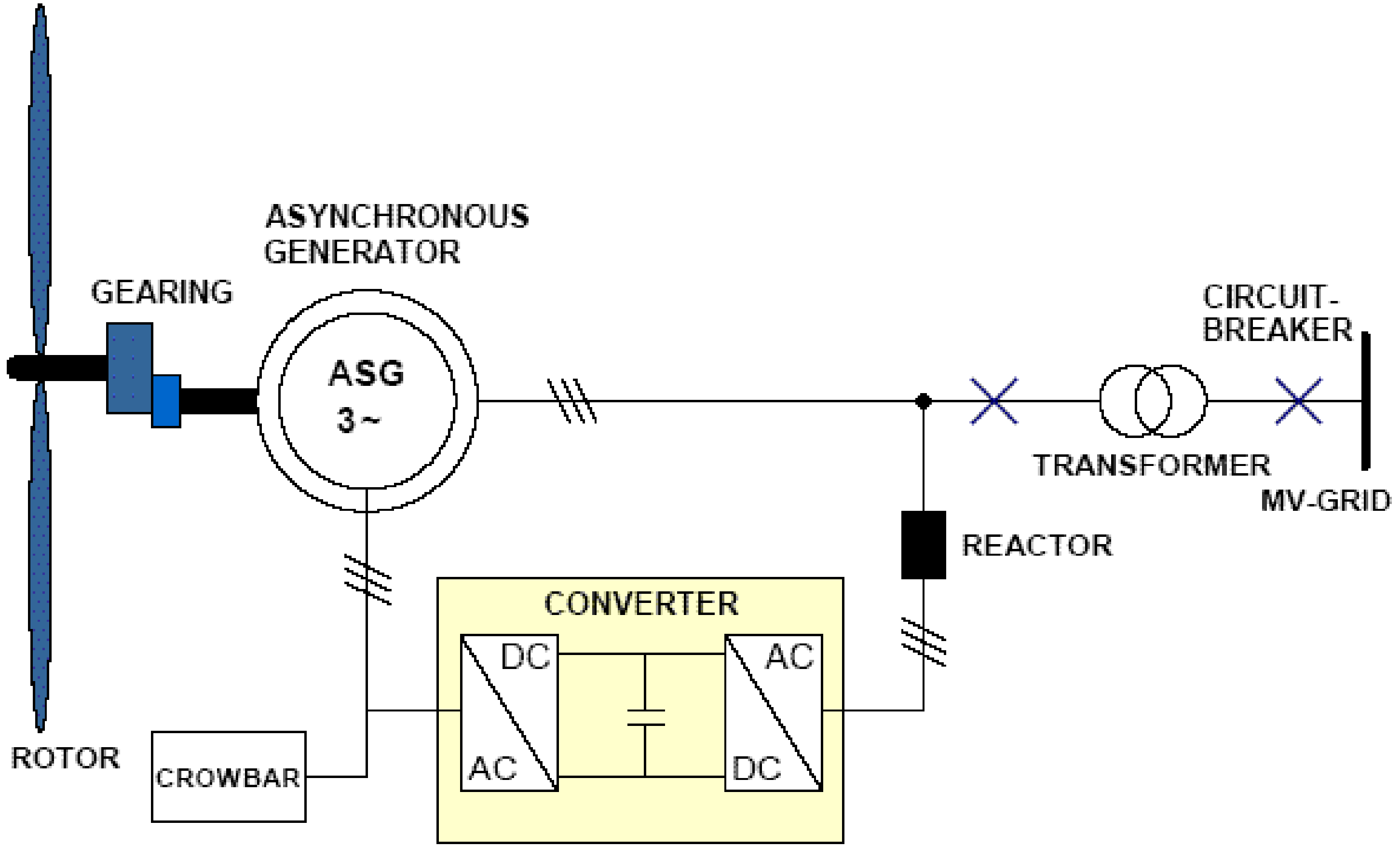
Electrical Protection

- Significant issue
- Need for communication
- Technology of smart relay protection
- Power flow directions and voltage conditions need to be considered
- Mal-operation of network protection can occur
- Fault levels dependent on mode of operation

Variety of Technologies

- Wind turbines
- Solar cells
- Gas turbines
- Fuel cells
- Microturbines
- Gas & diesel engines

Double Fed Induction Generator



Connection Costs

- Negotiation with utility can be difficult and protracted
- Shallow, deep or mixed connection cost
- Difficult with competitive market
- Participation in Ancillary services?
  - Spinning Reserve
  - Reactive power
  - Generally difficult

Role of ICT

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- Research now underway in many countries
- Optimum voltage control based on integral control of all the voltage controllable equipment in the grid
- Technology to utilize EG as a reliable source via centralized control
- Research on the configuration of distribution systems to utilize EG

Power Quality

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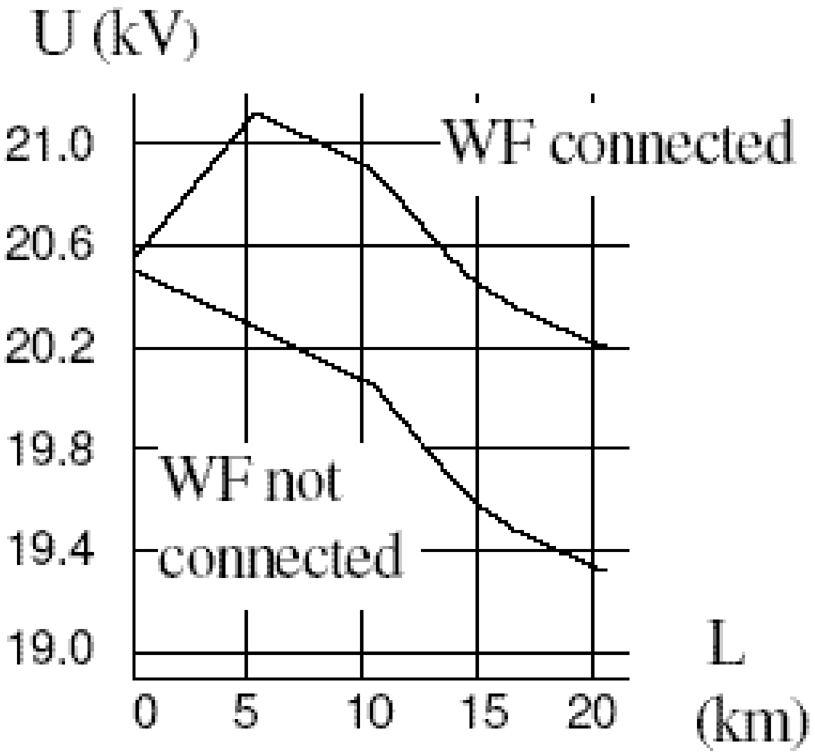
- Depends on energy source and conversion technology
- Flicker and voltage fluctuations
  - Slow voltage variations
  - Fast voltage variations
  - Variability in primary energy source
- Harmonic and Inter-harmonics
- Unbalance
- AS/NZS 61000 series of standards

Reactive Power and Voltage Control

› Connection of EG changes voltage profile
› Flow of active and reactive power



Reliability

- Level of redundancy
- Security of supply of energy source
  - Solar
  - Wind
- Energy source or capacity?
- Depends on design philosophy
- Intentional islanding can help to improve

Impact / Benefit to Security

- Generally difficult to gain benefit
- Intentional islanding can also help
- Depends on reliability of fuel source

Islanding

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- Traditionally utilities do not allow islanding
- MicroGrids more focus on islanding
- Remote locations with embedded generation
- Issues:
  - Synchronisation
  - Power quality
  - Energy balance
  - Safety
- More research required

Summary

- Embedded generation / distributed generation area subject of intense activity and interest world-wide
- CIGRE placing a lot of emphasis on this issue
- European Community moving to greater application of renewable energy
- Practical economic implementation remains a challenge
- Review carried out of issues associated with connection of embedded generation
- Examples of projects demonstrated
- The future is sure to change

2016 South Australian Blackout

- Blackout occurred due to critical weather conditions that damaged electricity transmission lines and distribution network.
- The wind damaged 23 pylons on electricity transmission lines including interconnectors to Victoria.
- The entire state was without electricity for 2 days and supermarket was suspended for 13 days.
- South Australia were mostly depended on wind energy.
- No proper planning and integration to divert or utilize the generated power

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Upcoming webinars: www.eit.edu.au/news-events/events/

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Q&A

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