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**Demonstrating the Capacity Benefits of  
Dynamic Ratings in  
Smarter Distribution Networks**

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## EU agrees 2020 clean energy deadline

Green lobby and politicians hail agreement to use 20% renewables within 12 years as climate change landmark

### • Political decisions

- Targets to decrease CO<sub>2</sub> emissions
- Targets to increase the use of renewable sources of energy
- etc., etc., etc.

#### Renewable energy potential

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27/11/2007

A new target to generate 50 per cent of Scotland's electricity from renewables by 2020, with an interim target of 31 per cent by 2011, has been set.

The Scottish Government's previous renewable target was 40 per cent by 2020.



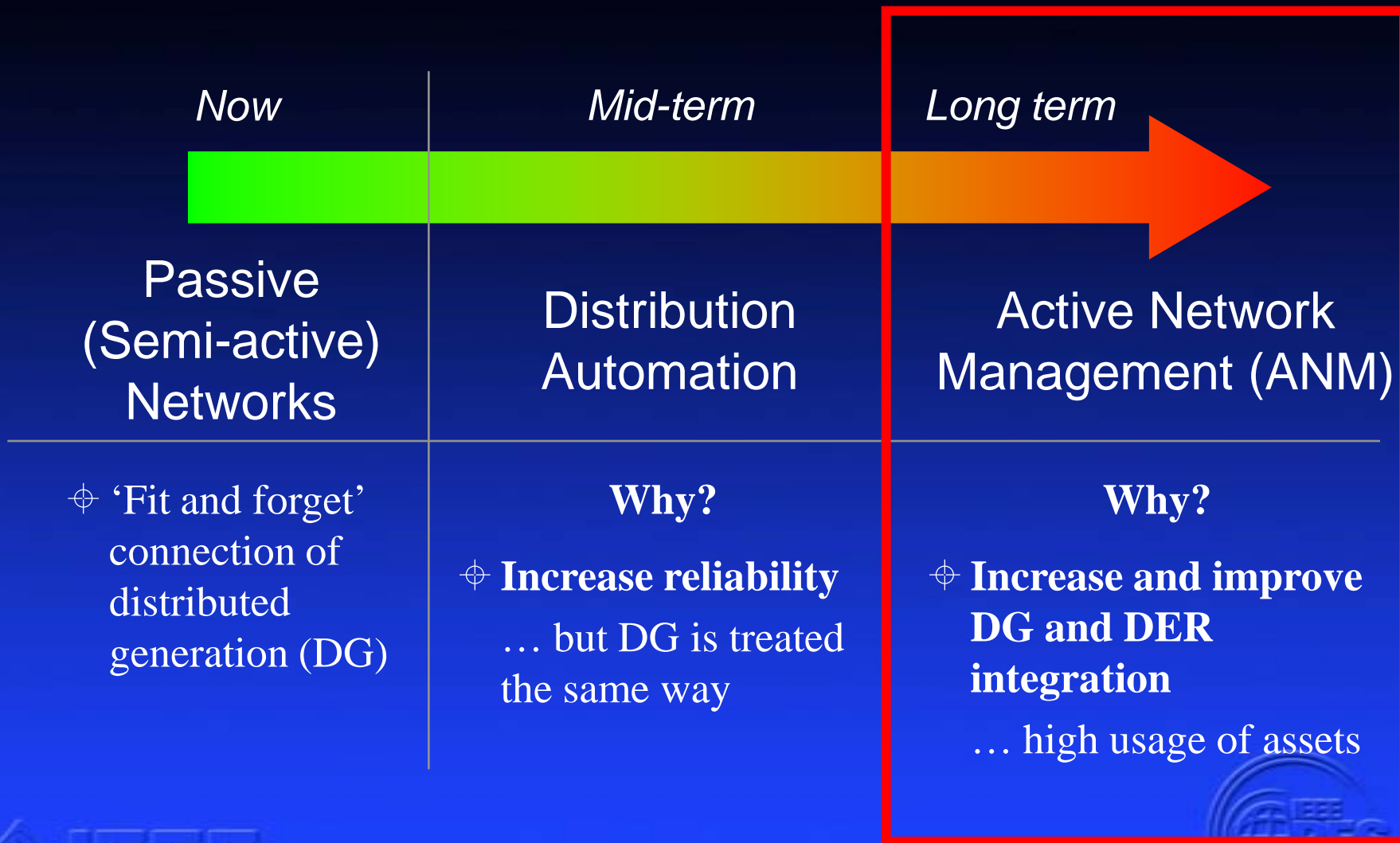
## Activity 3.1 “Strategies to maximise the absorption of new generation”

→ To what extent can innovative schemes (a more ‘intelligent’ network) increase the penetration of (renewable) Distributed Generation?

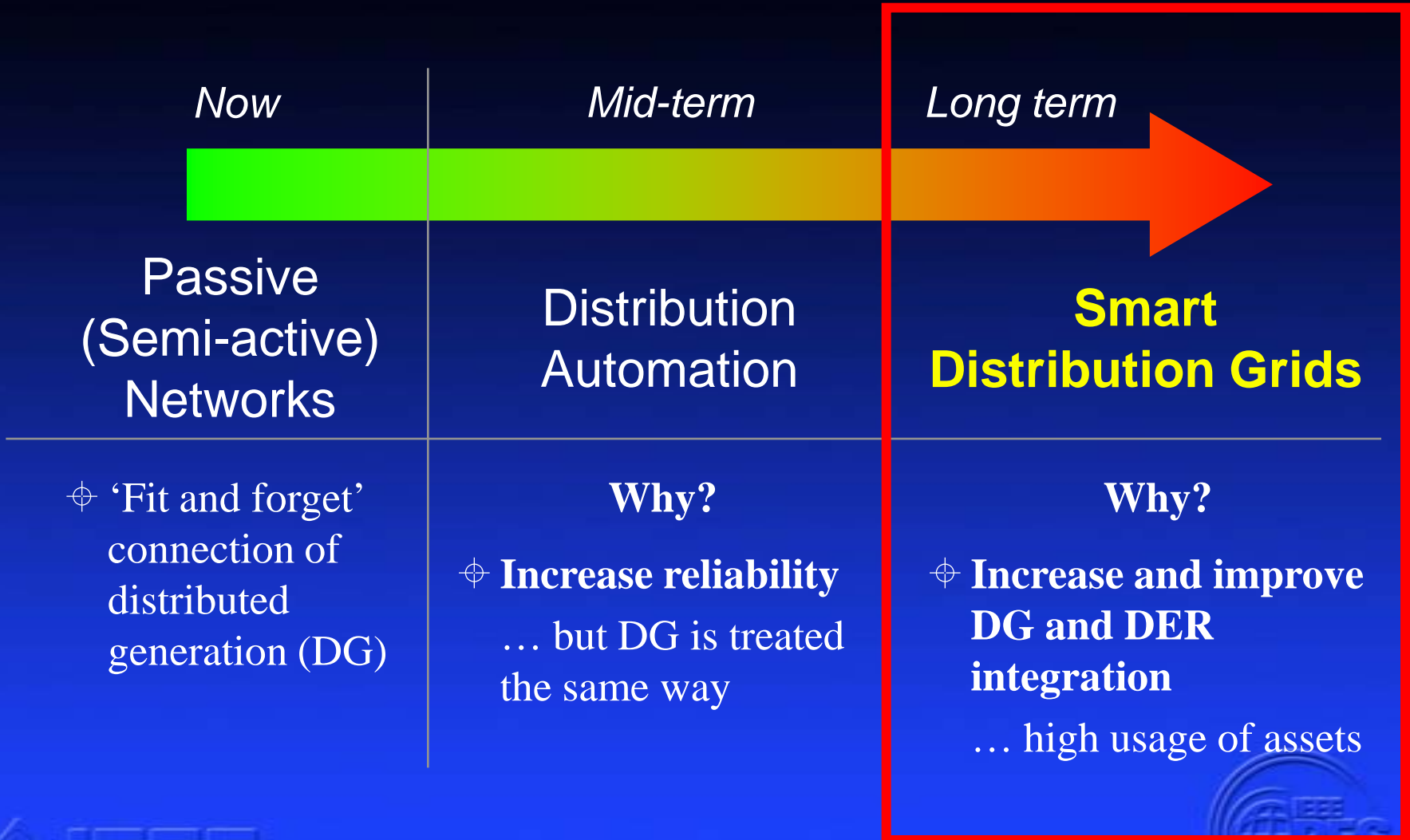


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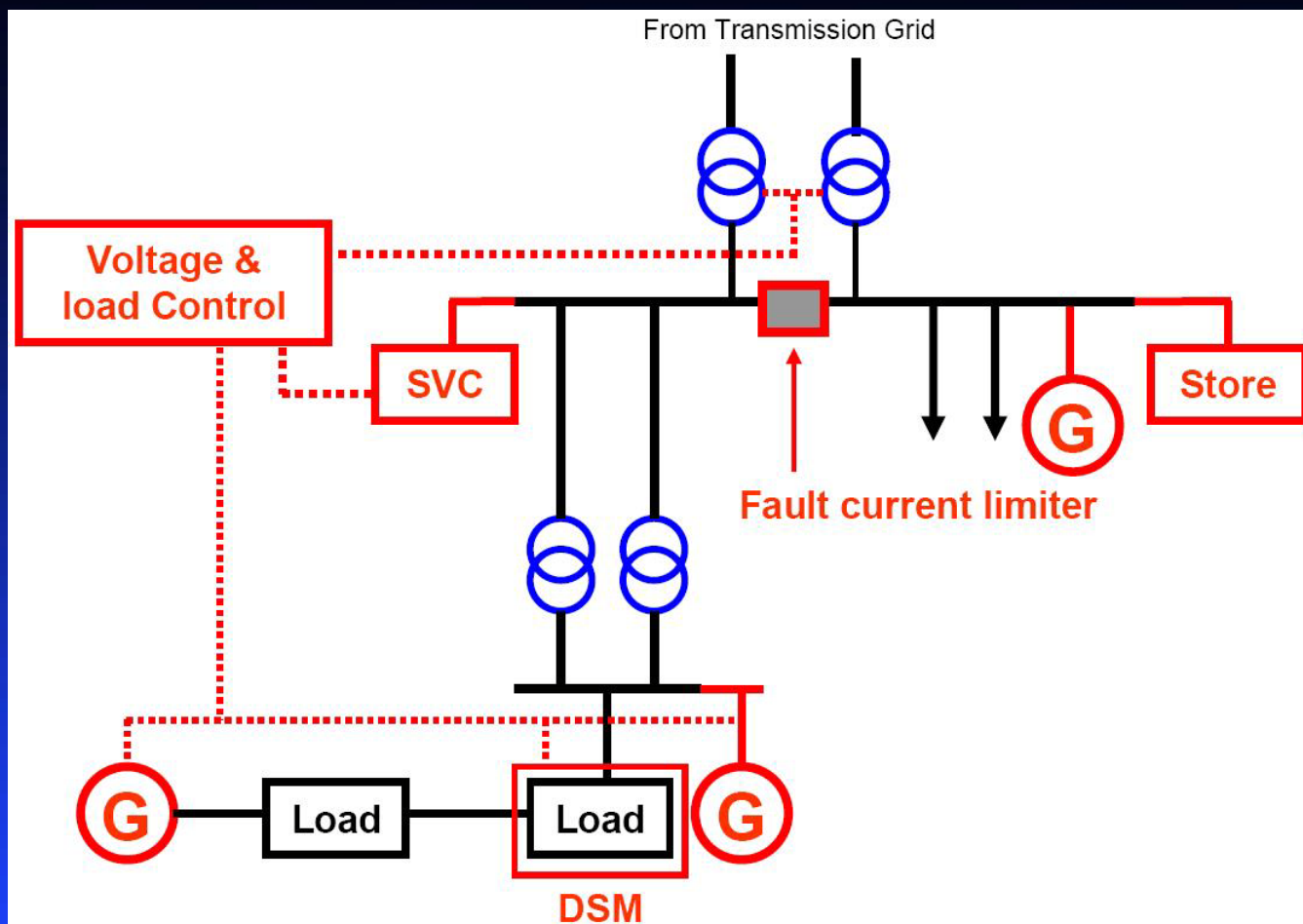
# Changing Networks



# Changing Networks



# Advanced Distribution Management System



Source: Ofgem

# UK Incentives for Facilitating the Connection of DG and Innovation in Distribution Networks

Distribution Price Control Review 4 (2005-2010)

- ✓ Innovation Funding Incentive (IFI)
  - R&D, 0.5% of the turnover for eligible projects
    - ... to have more innovation
- ✓ DG Incentive
  - £2.5/kW/year (for 15 years)
    - ... for DNOs to have a more proactive attitude
- ✓ Registered Power Zone (RPZ)
  - +£2.0/kW/year (for the first 5 years). Cap of £0.5m/DNO/year
    - ... to develop cost-effective approaches for connecting DG

**3 AUGUST 2009**

**R/29**

## **Ofgem's £6.5 billion investment proposals to boost customer service and cut carbon from regional electricity networks**

- **A £6.5 billion investment proposal for 2010-2015 will deliver new and renewed regional networks, building on £5.2 billion set in 2005-2010**
- **Ofgem requires companies to deliver investment plans for 17 per cent less than their forecasts**

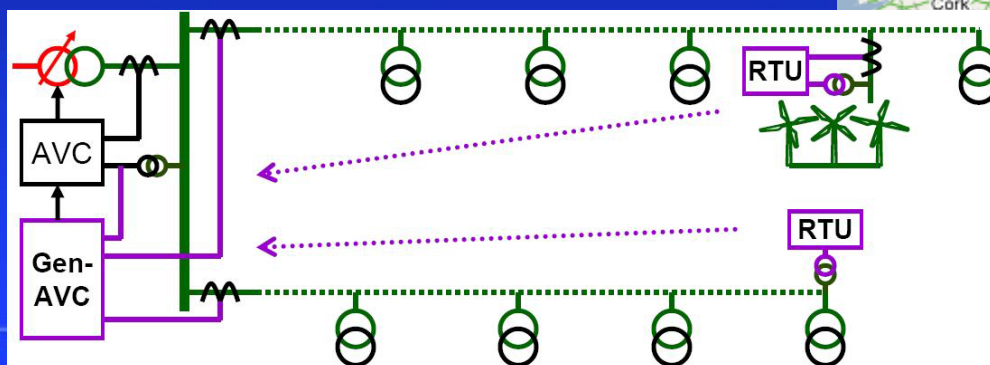
**New £500 million Low Carbon Networks Fund for large-scale trials of advanced technology and commercial initiatives**

- **Ofgem's package tough but fair deal that will deliver for energy customers today and in the future**

Energy regulator Ofgem has unveiled proposals that will deliver better customer service from the regional electricity network companies, maintain high network reliability and pave the way for further carbon reductions. The package will add an average of less than £4 a year to today's annual household electricity bill.

# RPZ – EDF Energy Voltage Constraints

- ✓ Coordinated control of OLTC
- ✓ Uses (measures/estimates) generation and demand data
- ✓ Can double the connectable DG capacity



# RPZ – Scottish and Southern Energy (SSE) Thermal Constraints

- ✓ The Orkney Islands have great wind resources but are connected to the mainland through submarine cables
- ✓ This system uses:
  - availability of the circuit
  - variability of wind power
  - variability of demand
- ✓ Significantly increases the export capacity



# RPZ – E.On Central Networks Dynamic Ratings

- ✓ Dynamic monitoring of line ratings (132kV) – increases the connection capacity of DG
- ✓ Helps transporting the energy from off-shore wind farms
- ✓ Line ratings is calculated using the ambient temperature and wind speeds
- ✓ Power donut ([www.usi-power.com](http://www.usi-power.com))



→ To what extent can innovative schemes (a more ‘intelligent’ network) increase the penetration of (renewable) Distributed Generation?

## **Demonstrating the Capacity Benefits of Dynamic Ratings in Smarter Distribution Networks**

# Thermal Ratings for Overhead Lines (UK)

Thermal ratings for overhead lines in the UK are calculated based on assumptions of certain weather conditions in particular seasons.

- ✓ Engineering Recommendation (ER) P27
  - 2°C (winter), 9°C (spring/autumn) and 20°C (summer)
  - Constant wind speed of 0.5 m/s
  - Zero solar radiation

The assumption of such a low wind speed neglects the potential cooling effect of the wind, thus giving a conservative rating value in many circumstances.

# Current Carrying Capacity of Overhead Lines

The current carrying capacity of overhead lines can be calculated through different methods.

## ✓ IEEE Std 738-2006

- At a given set of weather conditions,  $m$ , the (single-phase) ampacity for an overhead line  $l$  will be obtained considering the maximum permissible temperature of the conductor:

$$I_{l,m}^+ = \sqrt{\frac{q_{c,m} + q_{r,m} - q_{s,m}}{R(T_c^+)}} \text{ Amp}$$

- convective cooling
- radiative cooling
- solar heating
- resistance of the conductor



$$\text{dynamic } f_{l,m}^{+, (1,2)} = \sqrt{3} V_{b=\beta_l^{(1,2)}} I_{l,m}^{+, pu} \text{ pu}$$

- maximum 3 $\phi$  power flow

# Example

- 33kV, ACSR 2/0 conductor, with a diameter of 11.354mm, and 0.427 and 0.577  $\Omega$ /km of AC resistance at 25 and 75°C, respectively.
- Maximum ambient temperature adopted: 75°C.
- Conductor is sited at an elevation of 100 m above sea level and the wind direction is perpendicular to the axis of the conductor. Solar radiation is neglected.

| Season                         | Winter       | Spring/Autumn | Summer |
|--------------------------------|--------------|---------------|--------|
| Ta (°C)                        | 2            | 9             | 20     |
| wind speed (m/s)               | 0.5 (ER P27) |               |        |
| Ampacity                       | 270.4        | 257.6         | 235.9  |
| Max. 3 $\phi$ Power Flow (MVA) | 15.5         | 14.7          | 13.5   |
| wind speed (m/s)               | 2.0          |               |        |
| Ampacity                       | 370.7        | 352.8         | 322.5  |
| Max. 3 $\phi$ Power Flow (MVA) | 21.2         | 20.2          | 18.4   |

37% increase



# Absorbing More Renewables

## Incorporating Operation into Planning

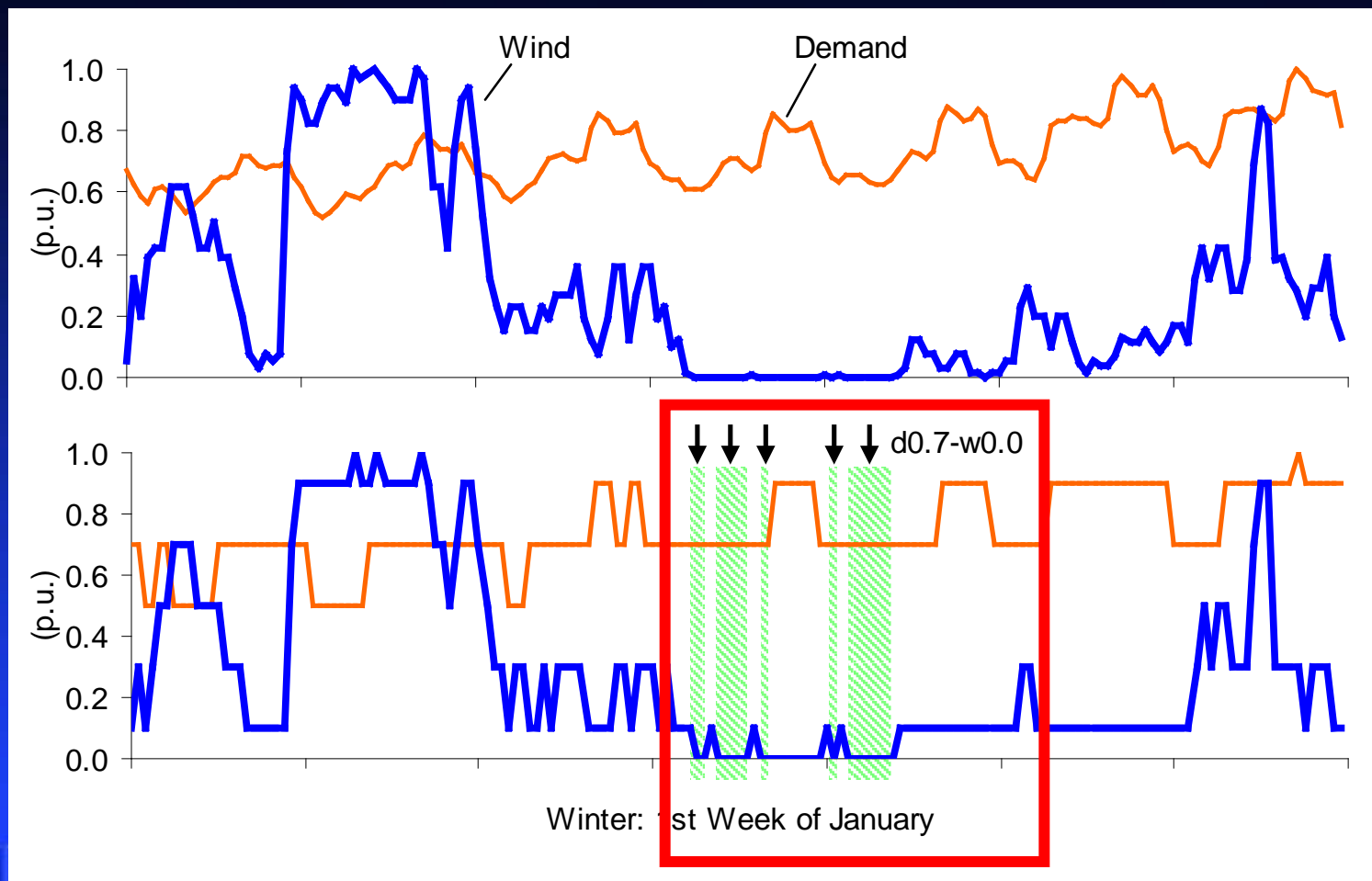
### *Maximise DG Capacity*

Subject to:



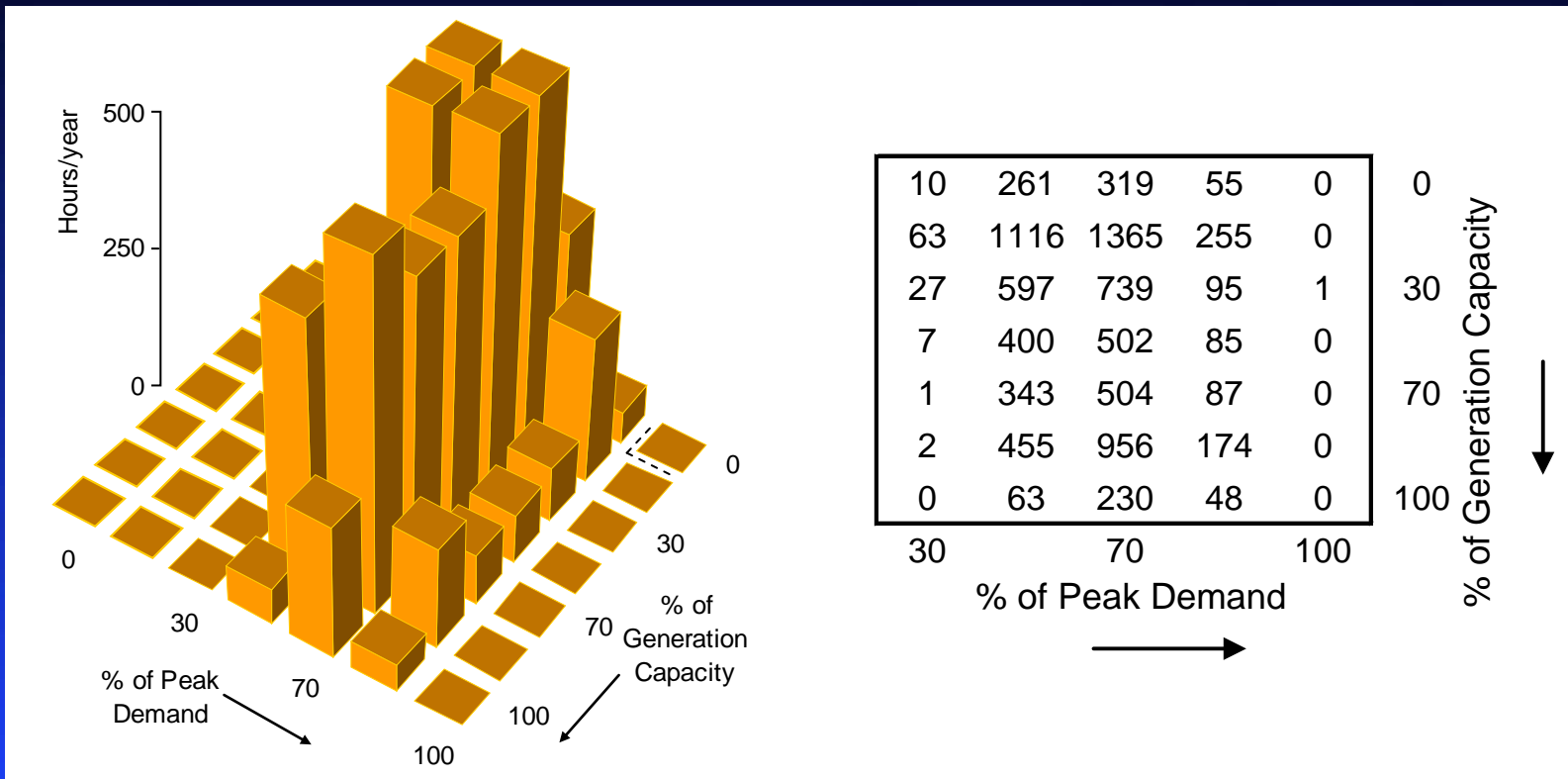
# Multi-Periods

## Handling the Variability of Demand and Generation



# Multi-Periods

## Handling the Variability of Demand and Generation

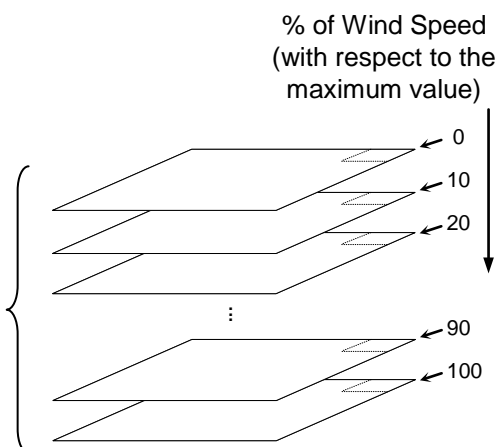
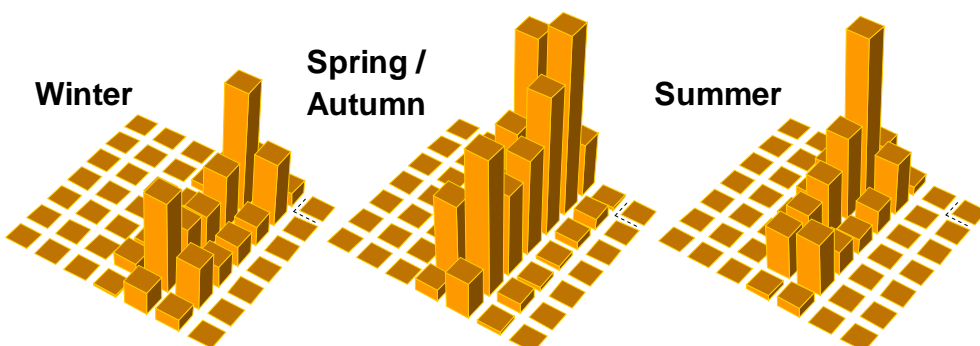
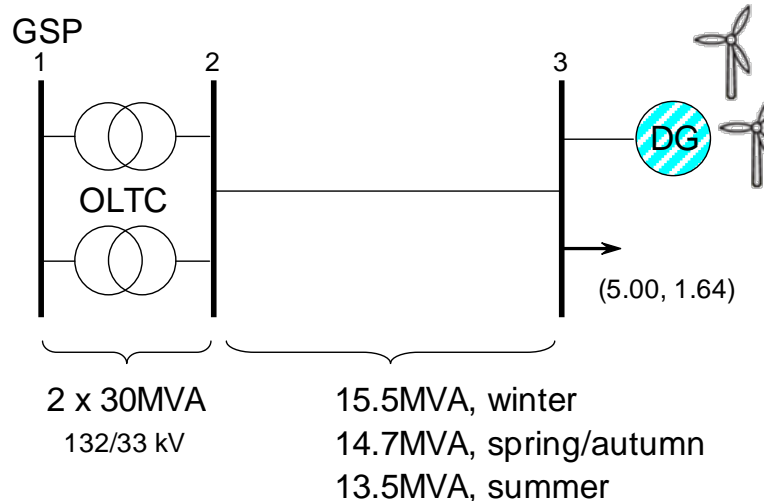


- The process is extended to cater for seasonality, wind speeds, temperatures, etc.

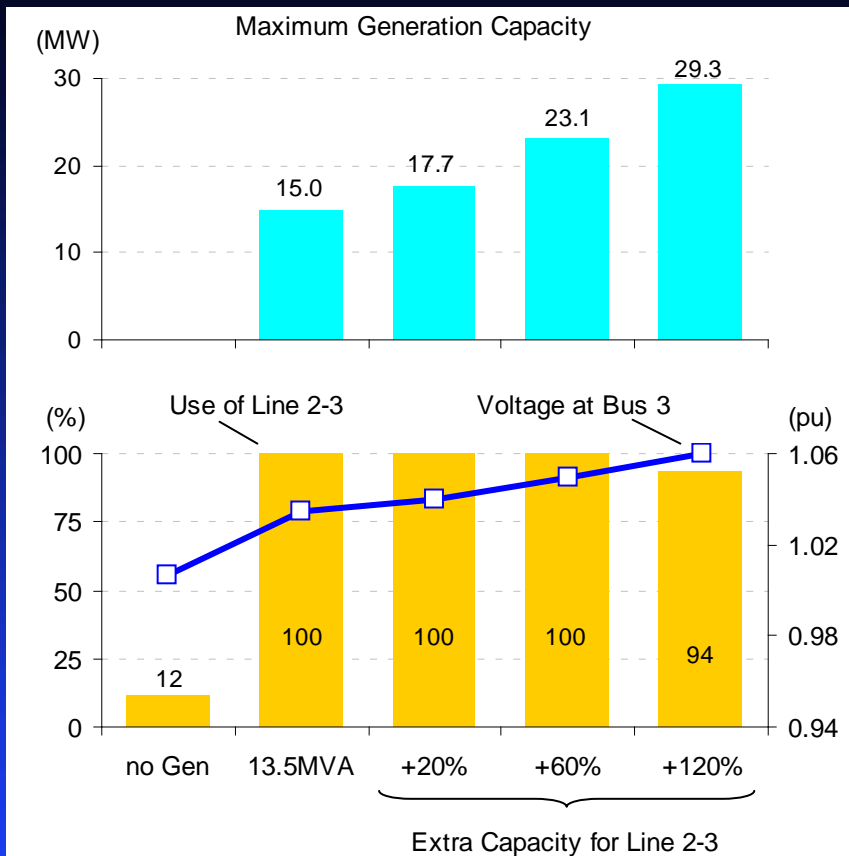
# Case Study

The 5km-long feeder is composed by ACSR 2/0 conductors.

Peak demand 5MW.



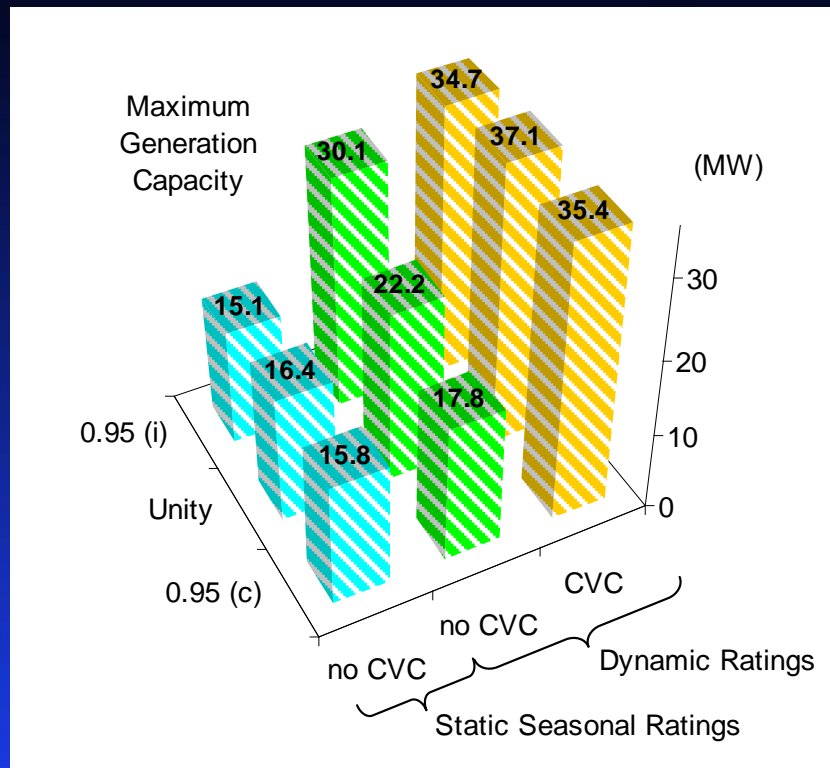
# Case Study: Snapshot



- Maximum generation capacity increasing the power flow limit of the connection line 2-3. Constant generation (unity p.f.) and minimum demand. Target voltage at the busbar is 1.010pu (summer).

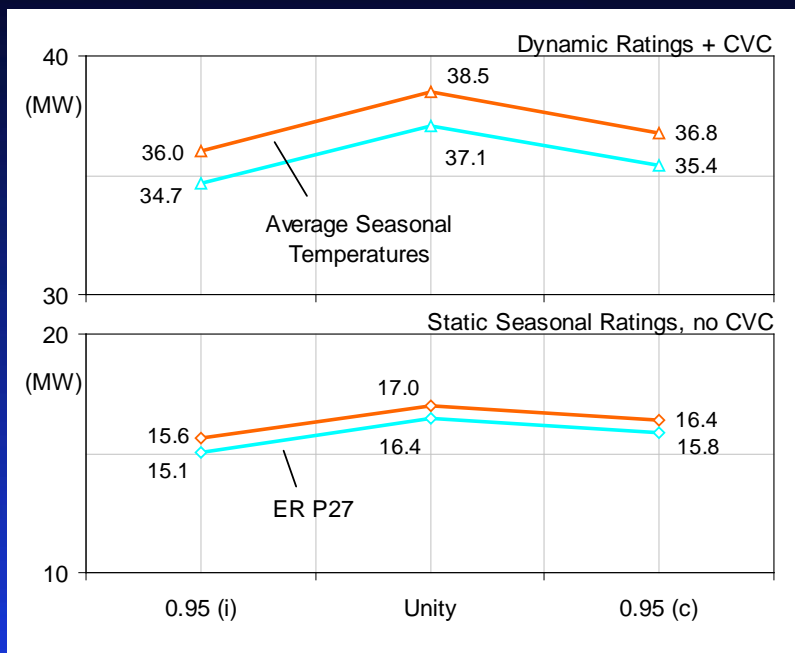
# Connectable (renewable) DG capacity

- Connectable wind power generation capacity (in MW) considering static seasonal ratings and dynamic ratings, as well as the use of coordinated voltage control (CVC).
- ER P27 temperatures are adopted.



➔ Dynamic Ratings + CVC + unity PF:  
 DG penetration doubles that without ANM

# Connectable (renewable) DG capacity



- Average seasonal temperatures derived from the 2003 time-series data for central Scotland (3.9°, 9.2°, 15.2°C, in winter, spring/autumn, and summer, respectively)

➔ This new set of temperatures translated into an average increase of 3.7%

# Conclusions

- Windy sites are ideal for the harvesting of such renewable resource. At the same time, given the cooling effect of wind, larger volumes of power can be transferred through overhead lines without reaching critical points. **This is a win-win scenario where the resource being harvested also frees transfer capacity that otherwise would be achieved with conventional reinforcements.**

# Conclusions

- Compared to the widely used passive operation of distribution networks, **very high penetration levels** of new variable generation capacity **can be reached** by strategically adopting **Smart Grid-like control schemes**.

# Conclusions

→ This AC OPF-based **planning tool allows quantification** of the benefits in terms of the **ability of innovative schemes to ‘free up’ capacity**, and thus, **help justify the corresponding investment.**

It is important, however, that **each solution**, or the combination of them, **should be assessed on a case-by-case basis** since network characteristics drive the performance and cost-effectiveness of each scheme.

# Thanks!

## Questions?

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