Towards Low-Carbon Distribution Networks

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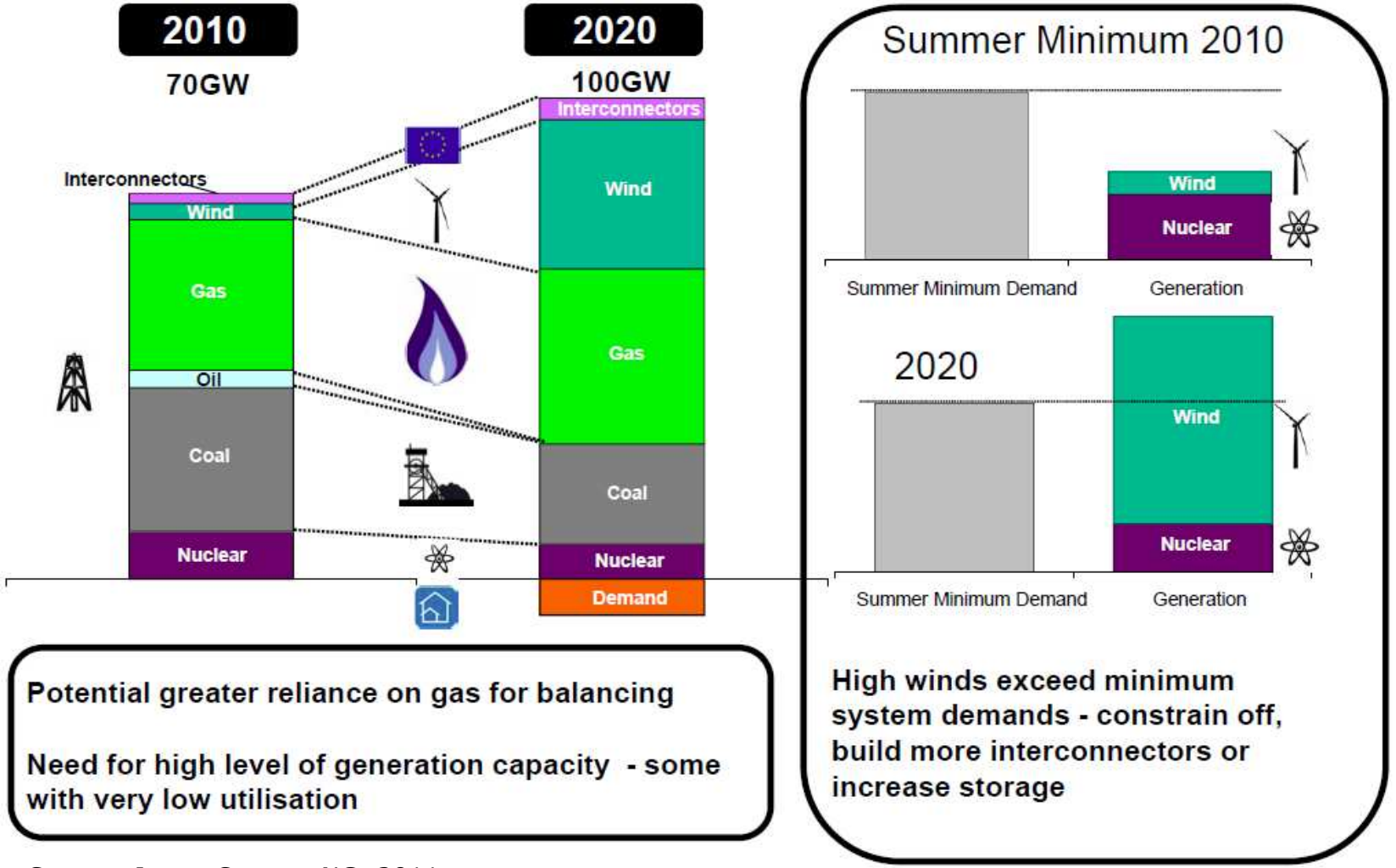
FCO Asia-Pacific Smart Grid Mission

Dr Luis(Nando) Ochoa

- Lecturer (joined the EEPS Group in Jan 2011)
  - Chair of the IEEE-PES UKRI Chapter
  - Chair of the IEEE-PES Modern and Future Distribution System Planning WG (PSPI)
  - Co-Chair of the CIGRE Task Force on Methods for Active Network Planning (WG C6.19)
- Current Team:
  - PGR: 3 PhD Students, 1 PDRA
  - UG: 1 MEng Team Project (4th year), 1 3rd-year Project
- Current Projects:
  - EDF R&D (France) "Flexibility"
  - ENWL (UK) "Low Voltage Network Solutions"
  - ENWL (UK) "Voltage Management"

National Grid: Changing Dependencies



Source: Jenny Cooper, NG, 2011

The UK Context for Distribution

- Perhaps the most competitive electricity market in the world (full unbundling)
- 9 Distribution Network Operators (DNOs)
- Business regulated by Ofgem
- Assets in <132kV (LV and HV) account for 50%+ of the value of GB electricity networks
- A significant part of the assets installed during the 1950s and 60s

Towards Low-Carbon D-Networks

In addition to renewable distributed generation (DG):

- Government incentives for micro/small-scale PV generation
- Government incentives for people to buy electric vehicles (EVs)
- Full smart meter rollout by 2020
- Electrification of heat, advent of smart appliances?

Towards Low-Carbon D-Networks

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**

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

significantly to improve their connections service

- **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.

Distributed Energy Resources: The Challenges

- LV Distribution Networks (400V)
  - Voltage rise due to PV panels (drops due to EVs?)
  - Thermal limits, Are the wires fit for purpose?
  - More unbalances? etc.
- HV Distribution Networks (11kV and 33kV)
  - Voltage rise due to wind power (rural networks)
  - Increase in short circuit level (urban underground)
  - Power quality, "Islanding" and Protection
  - Increased energy losses? Variability?
- EHV Distribution Networks (132kV)
  - Thermal limits
  - Stability and reserve requirements
  - Variability?

Observability

Controllability

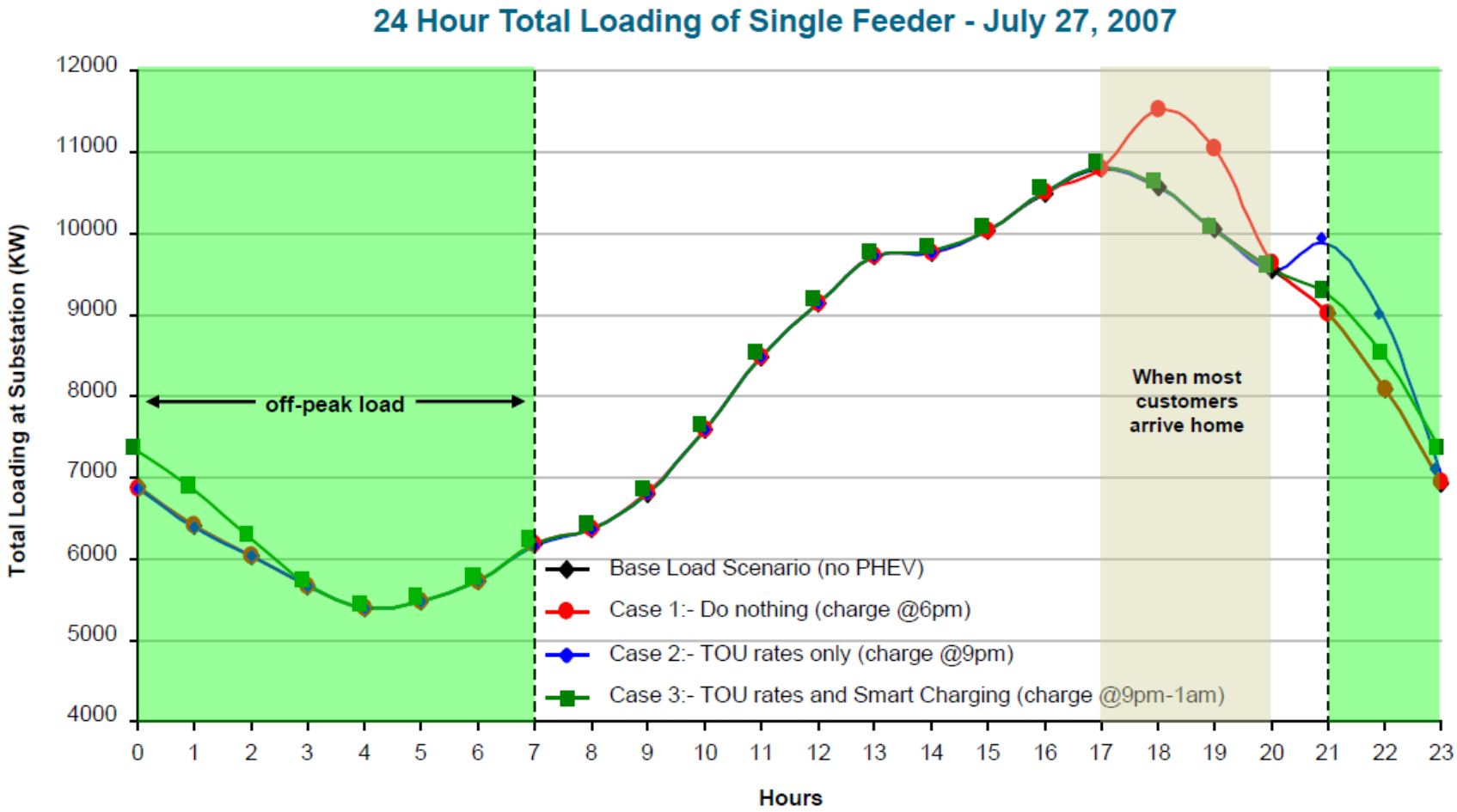
Voltage Management

...

Thermal, Fault Mgmt

Integration of Solutions

Electric Vehicle Charging (Urban Feeder)



Source: EPRI. Feeder of Northeastern utility feeder during urban summer peak with 2,778 residential customers. EV penetration = 10%. Case 1 –3 charge @ 240V, 12A

Storage: Changes Everything

- The 'holy grail' of power systems
- Technologies: batteries, flywheels, compressed air, etc.
- Applications:
  - Frequency control
  - Peak shaving
  - Constraint management (voltage, thermal)
    - active and reactive support
  - Intentional islanding?
  - Ancillary services?

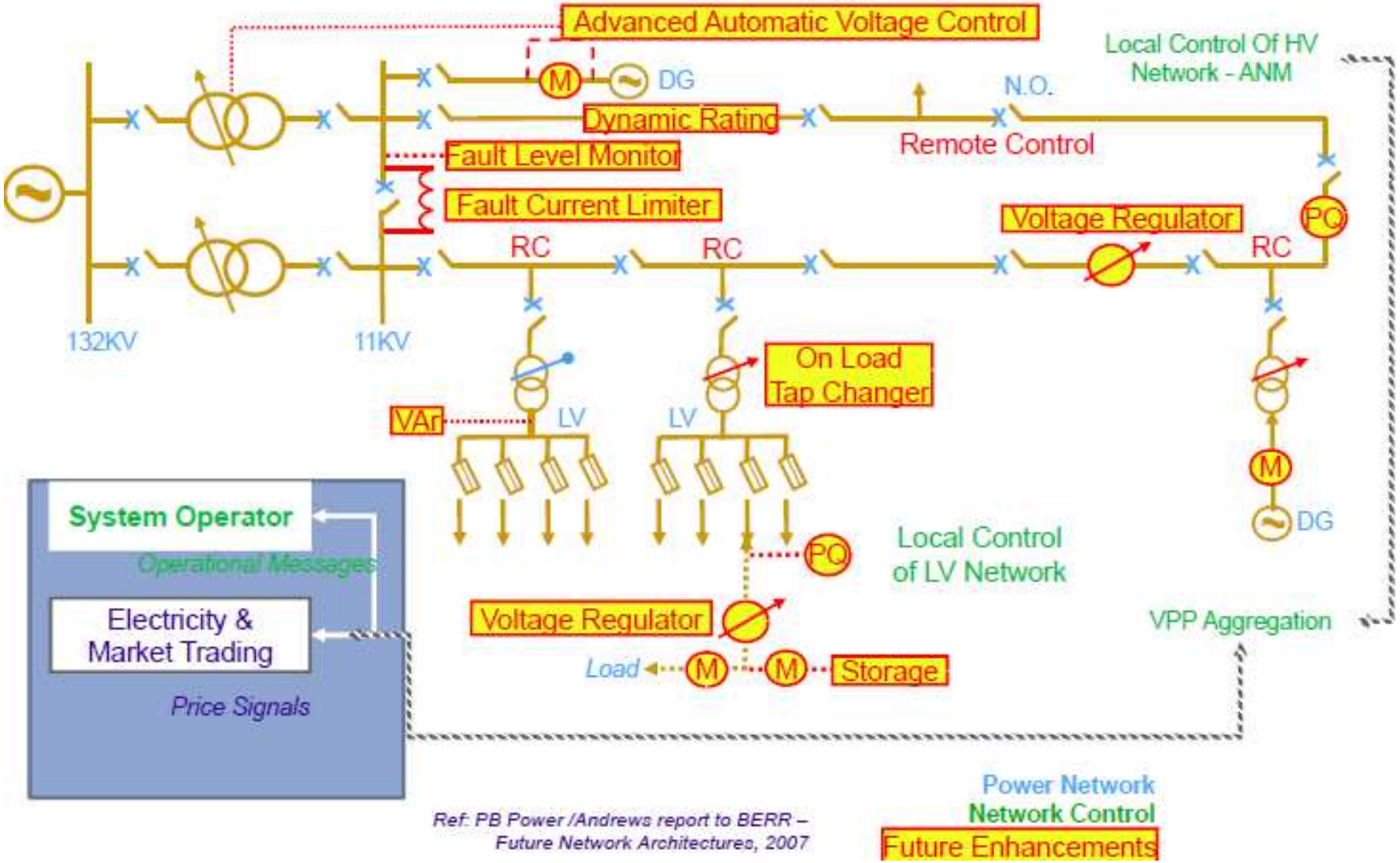
SSE: Shetland
NaS Battery
1MW, 6MWhr

Our Power System Tomorrow: The Smart Grid

and the backbone?

the electricity delivery system

Functional Requirements in D-Networks



Ref: PB Power /Andrews report to BERR – Future Network Architectures, 2007

(Some) Research Questions

Distributed Generation (DG) – Planning & Operation

- To what extent can innovative schemes (a more 'intelligent' network) increase the penetration of (renewable) DG?
- Can DG be used to provide support to the system?
- To what extent rule-based control will handle evolving (in complexity) systems?

Control of Network Devices/Participants

- Centralised or Decentralised? Distributed?

Monitoring

- How to manage large volumes of data in order to provide meaningful results?

Absorbing More Renewables
Incorporating Operation into Planning

Max/Min Objective Function

Subject to:

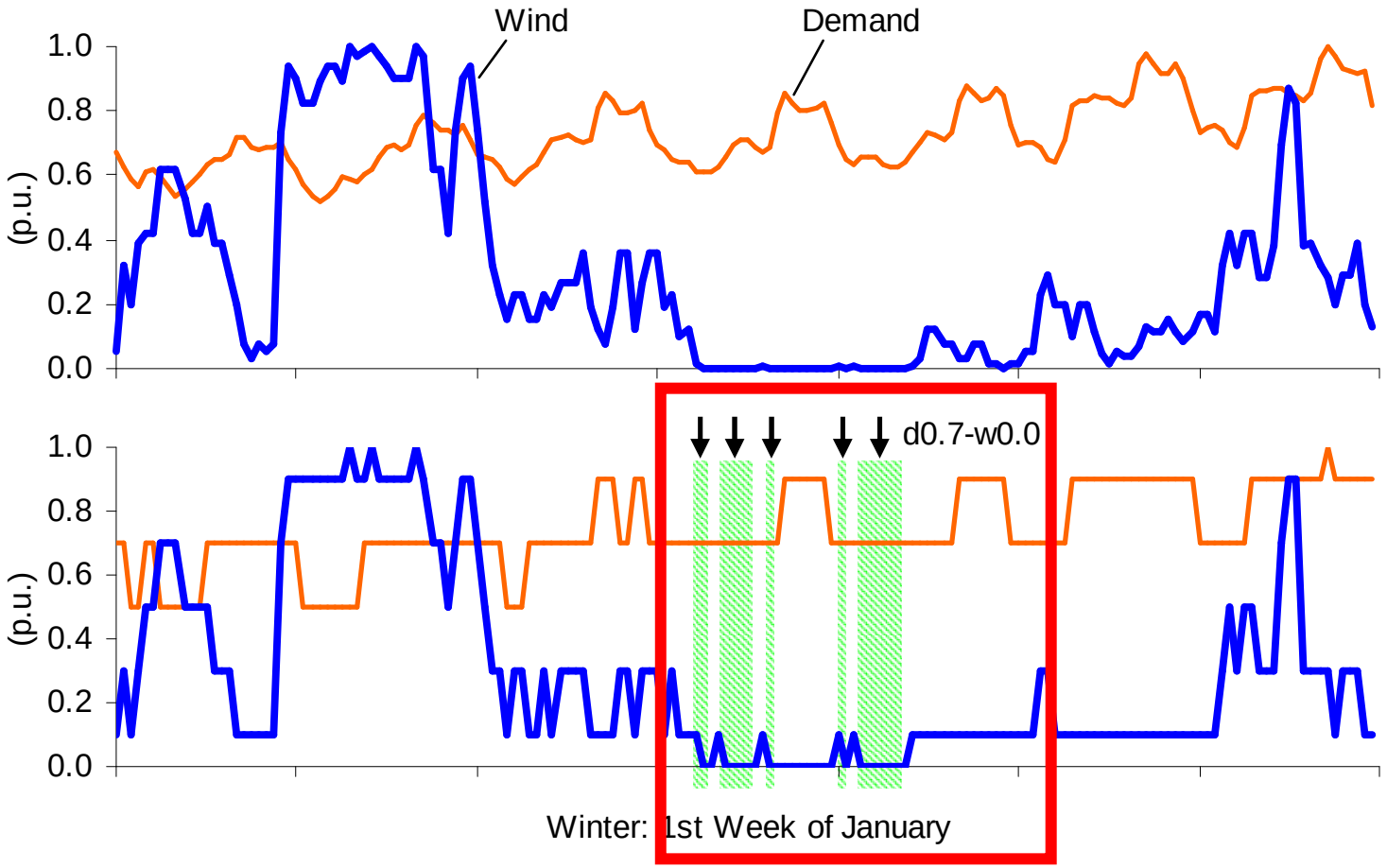
Multi-Period AC OPF + Smart Grid Control Schemes

Basic AC OPF
- real and reactive nodal power balance
- voltage level constraints
- voltage angle set to zero for the reference bus
- thermal limits (lines and transformers)
- constant power factor operation of DG units

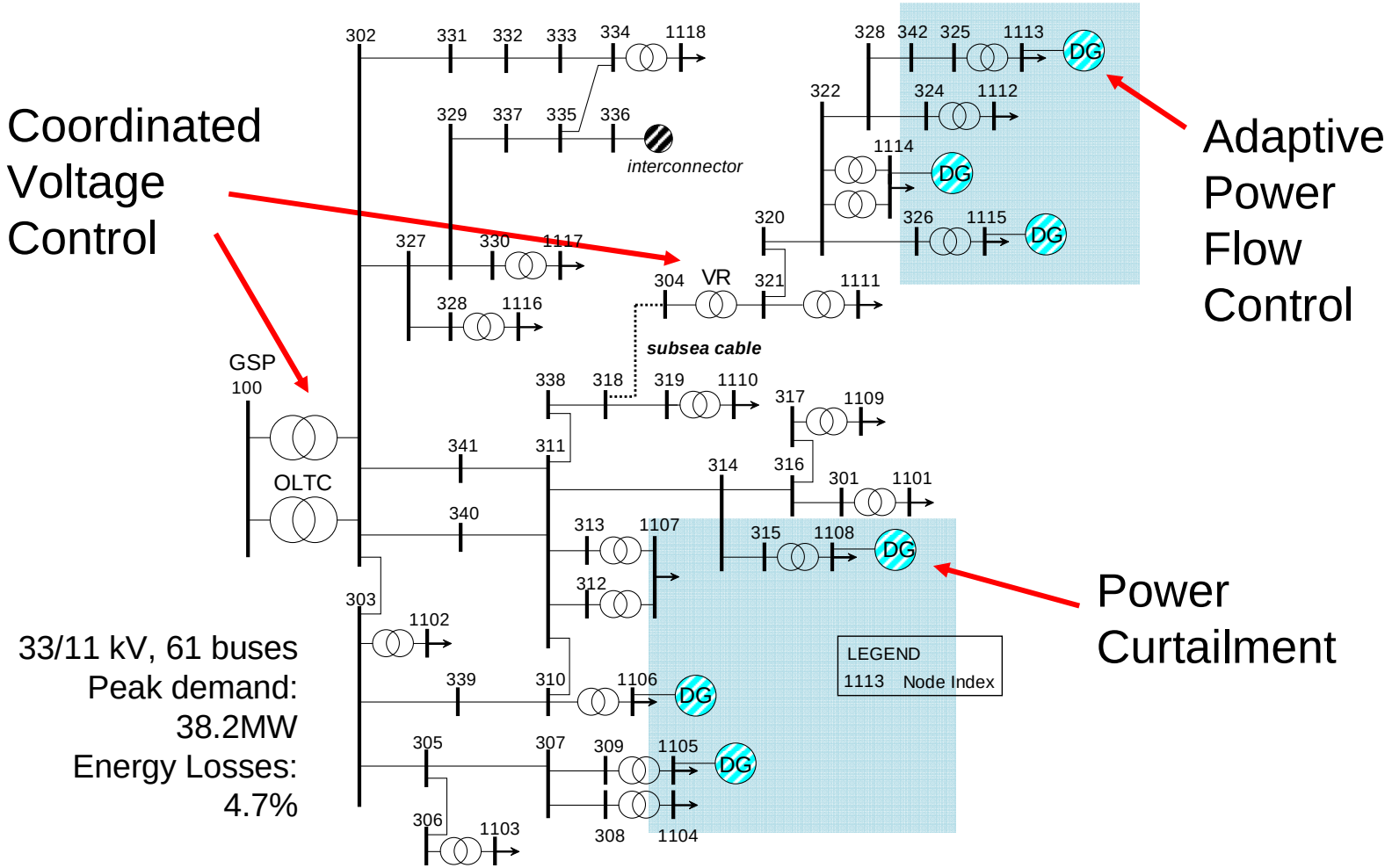
New Constraints
- voltage step change
- N-1 security constraints
- reverse power flow constraints
- fault level constraints
- etc., etc.

New Control Schemes
- coordinated voltage control
- adaptive power factor control
- generation curtailment
- dynamic ratings
- etc., etc.

Multi-Periods
Handling the Variability of Demand and Generation

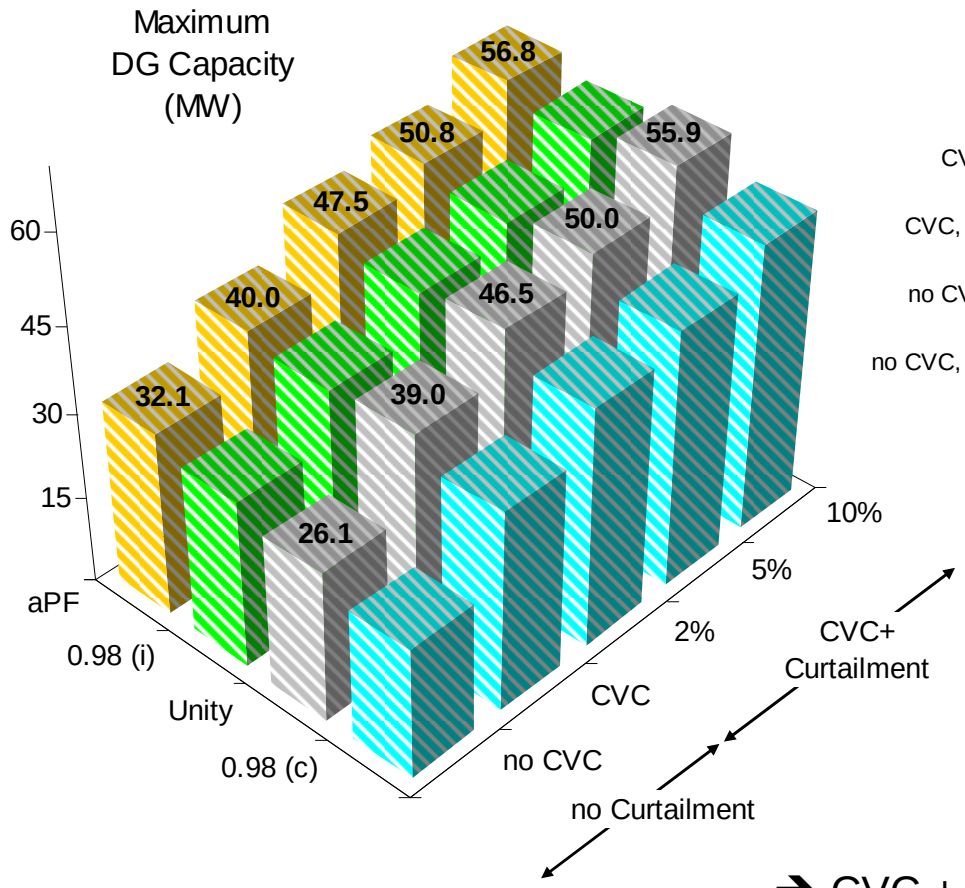


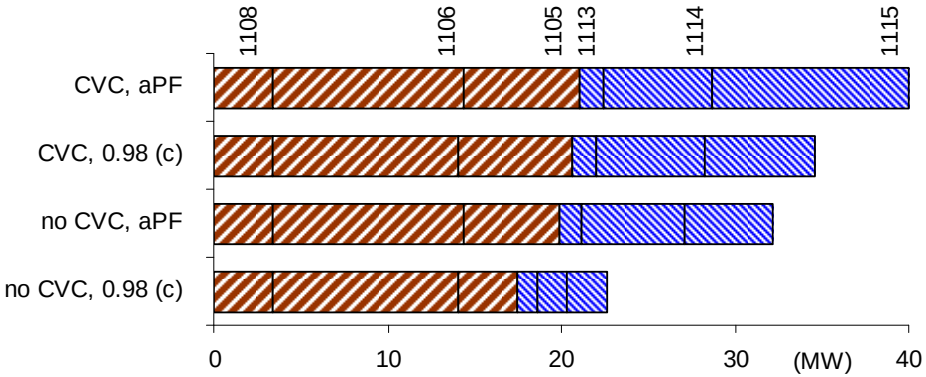
Case Study: UK GDS EHV1



Connectable (renewable) DG capacity

Maximising DG Capacity





Locational Breakdown

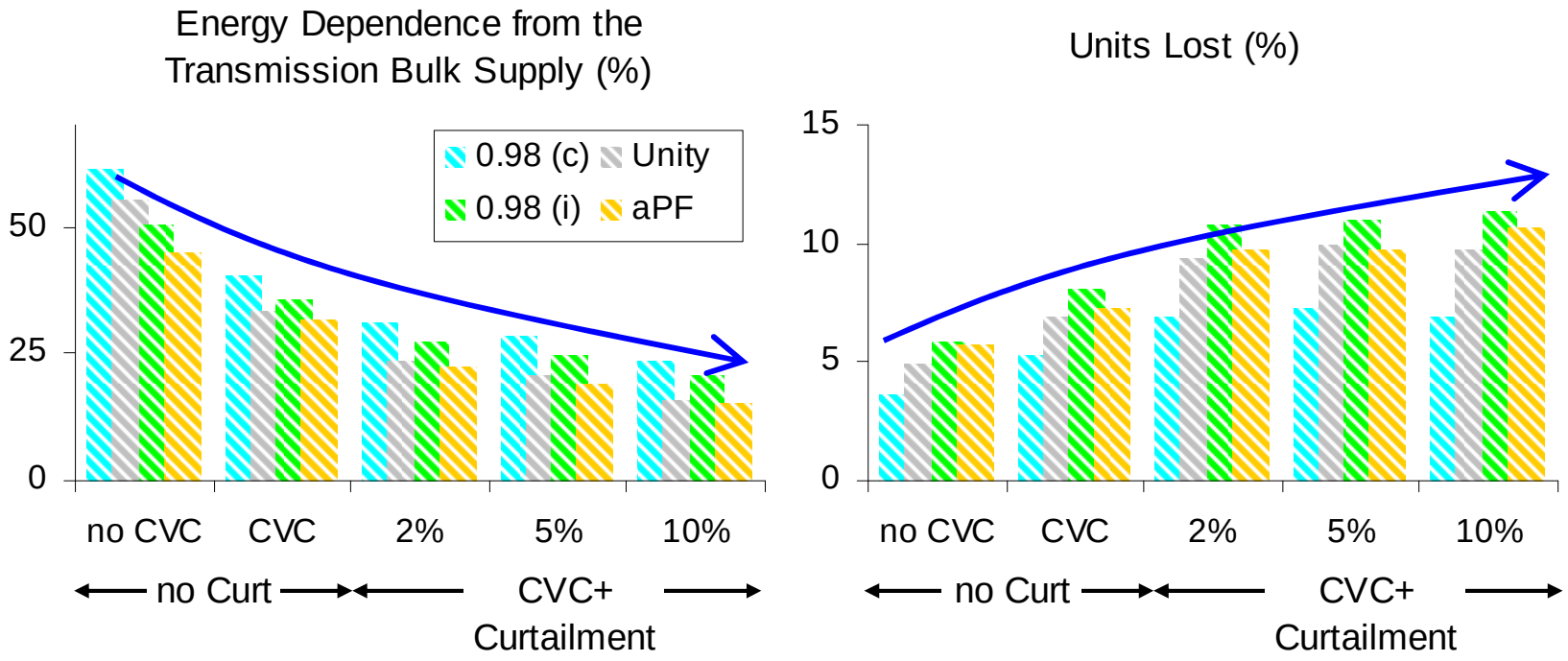
Mainland / Island

(no curtailment)

➔ CVC + adaptive PF control + 2% curtailment:
DG penetration of 124% (relative to peak demand)

Connectable (renewable) DG capacity

Maximising DG Capacity



➔ CVC + adaptive PF control + 2% curtailment: 9.7% of losses and only 22% dependence

Challenges Ahead

- The proposed ac OPF techniques might find limitations for very large networks with a high number of controllable participants and multiple resource profiles.

  → **tailored, specialised solvers**.

- Further work is needed to prove its value against control based on simple sets of rules.

  → **RTDS-based integration with centralised classical optimisation vs. rule-based control**.

- Monitoring needs to be deployed cost-effectively.

  → **LV-HV distribution state estimation to determine optimal deployment of devices**

- Understanding better LV networks.

  → **LV network characterisation**

IEEE Power & Energy Society

Innovative Smart Grid Technologies (ISGT) Europe 2011

Manchester, 5-7 December

http://www.ieee-isgt-2011.eu/

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Thanks for your attention!

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