SmarterGrid: Challenges and Opportunities

-Keynote at 4th Smart Grid Symposium

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  - *Global drivers*
  - *Transitions in Power Industry*
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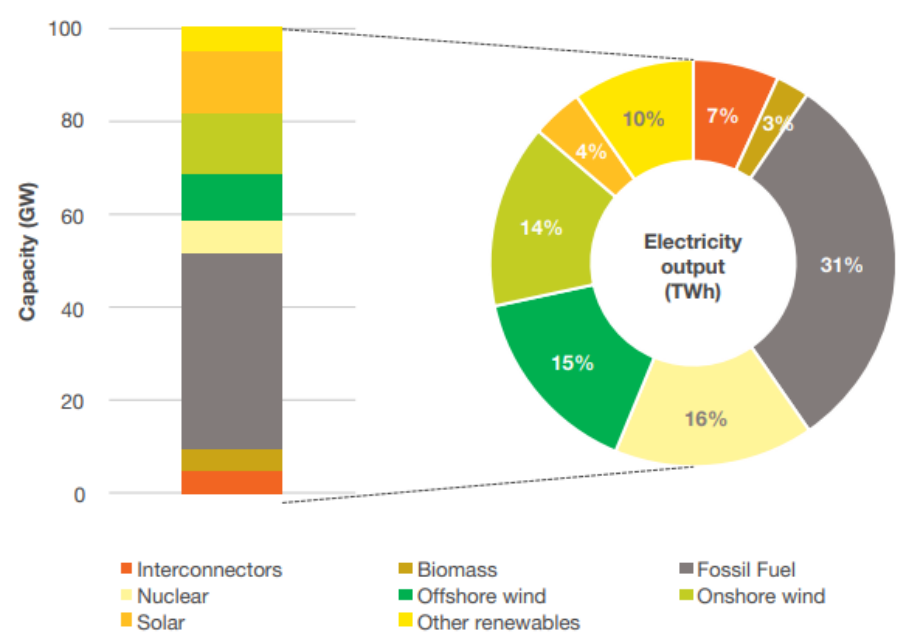
Introduction
- Global drivers

- **Decarbonation: Climate Change, COP26**
  - ✓Net Zero Targets
  - ✓Low Carbon economy
- **Digital Transformation**
  - ✓Digitization
  - ✓Digitalization
- **Decentralization: Major Infrastructures, incl.**
  - ✓Transportation
  - ✓Heat
  - ✓Electricity
  - ✓Town/city planning

Introduction
-Transitions in Power Industry– *Unprecedented!*

- **Energy Scenarios Changes:**
  - High penetration of renewable energy - IBGs: Wind farms, Storage
  - Power Electronics dominant: HVDC links, FACTS, SynchComp/SVCs, Smartwire
  - Significant decline in thermal power plant: phasing out coal fired plant
- **Digital transformations**
  - IEC61850 Based digital substation
  - MPLS telecoms
  - Data based network control
  - Data based Asset management
- **Energy network emerging**
  - Direct connections to Transmission and Distribution networks
  - Micro-Grid
  - EV Charging points

Introduction
-UK Generation Mix – Roadmap from 2020 to 2050 (1/20

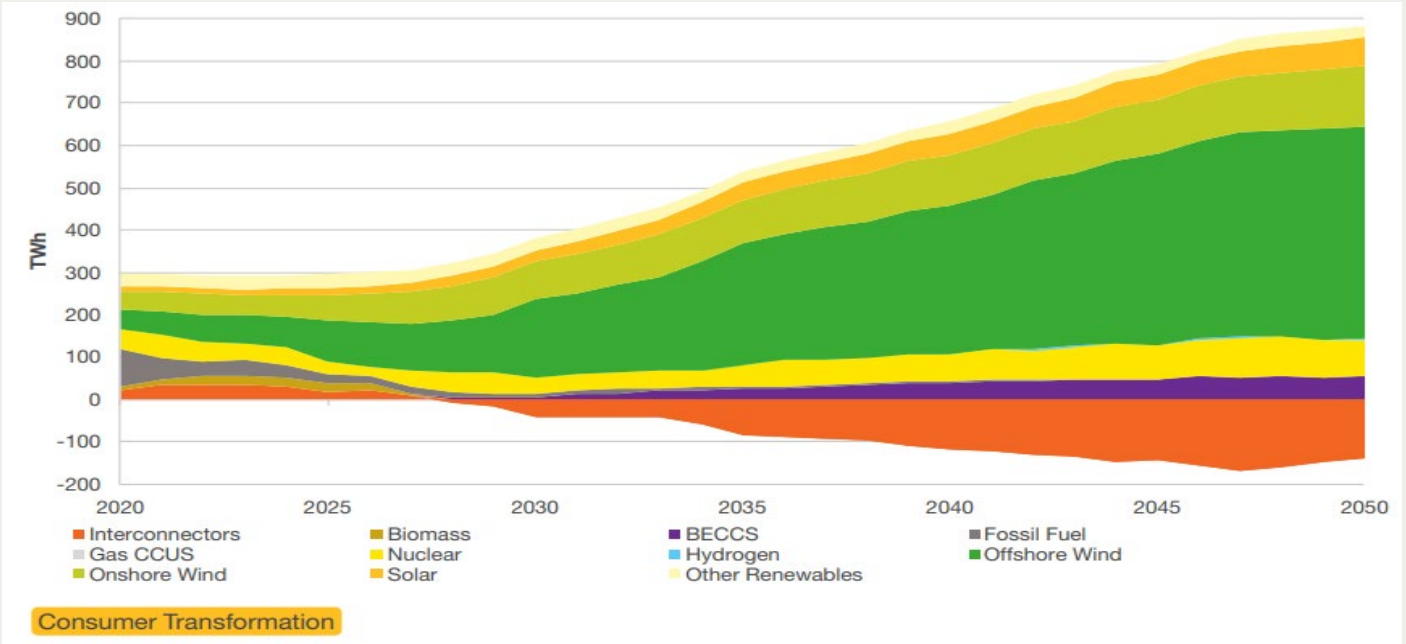


Generation Mix 2020

Global Drivers

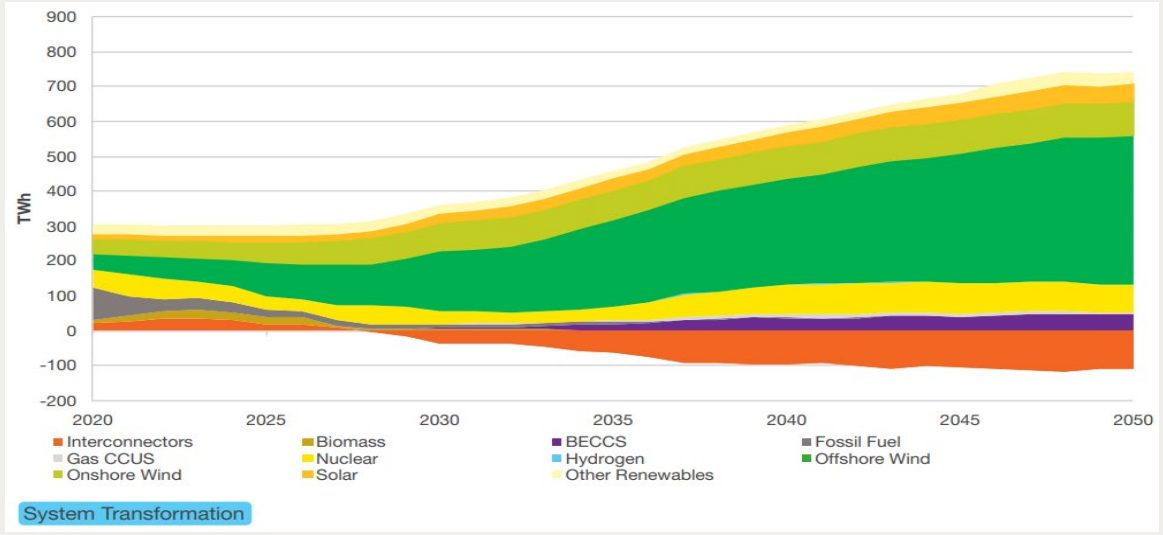
- Climate Change
- COP26
- UK's Ambitious Net Zero Target
- Low Carbon Economy

- Customer Transformation (CT)
- System Transformation (ST)
- Leading the Way (LW)
- Steady Progression (SP)

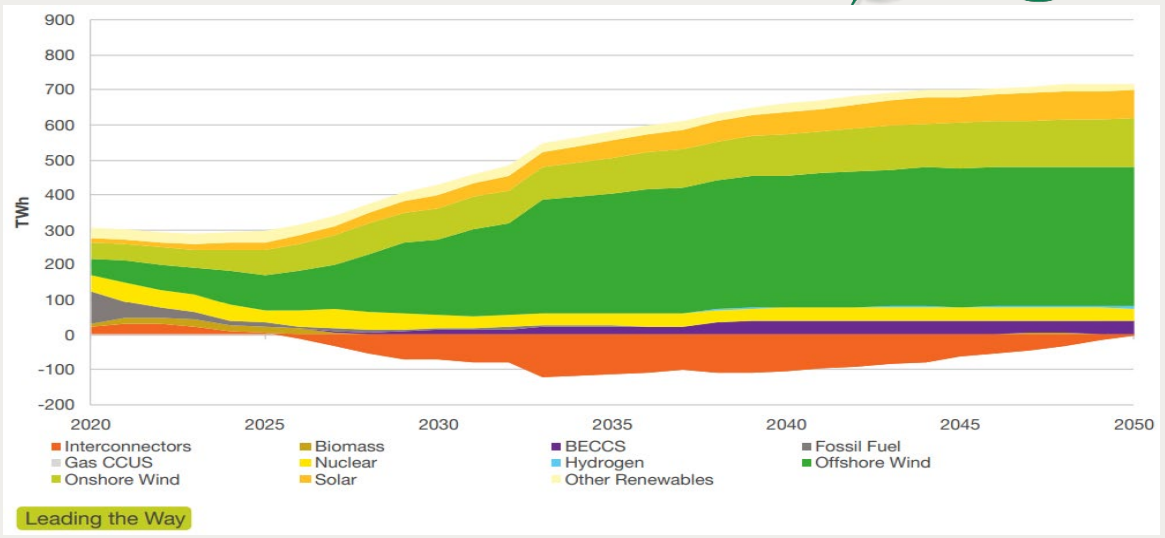


Introduction

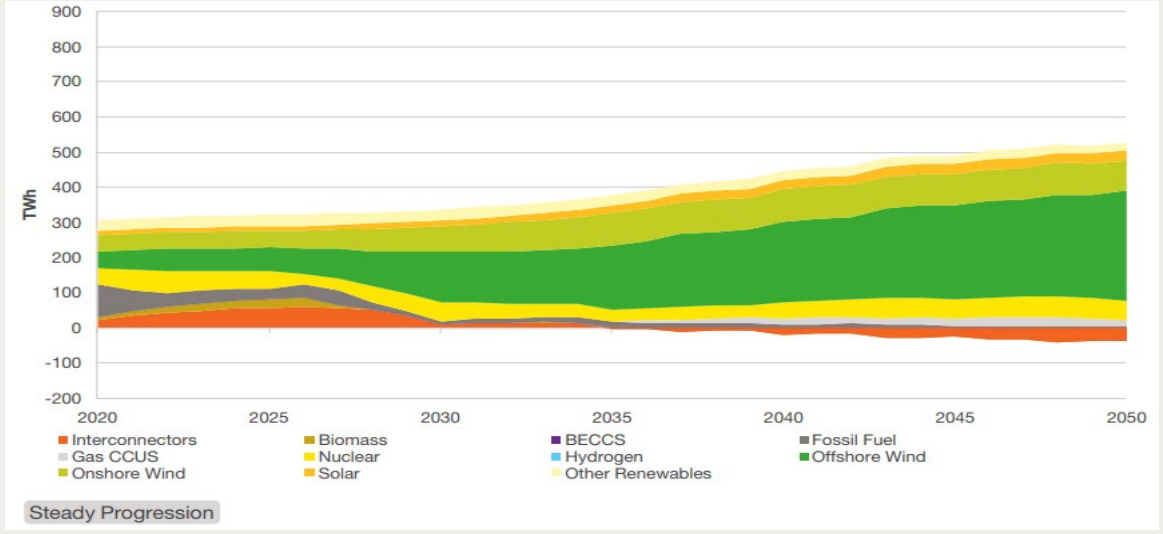
- Generation Mix – Roadmap from 2020 to 2050 (Continued) 2/2



System Transformation



Leading the Way



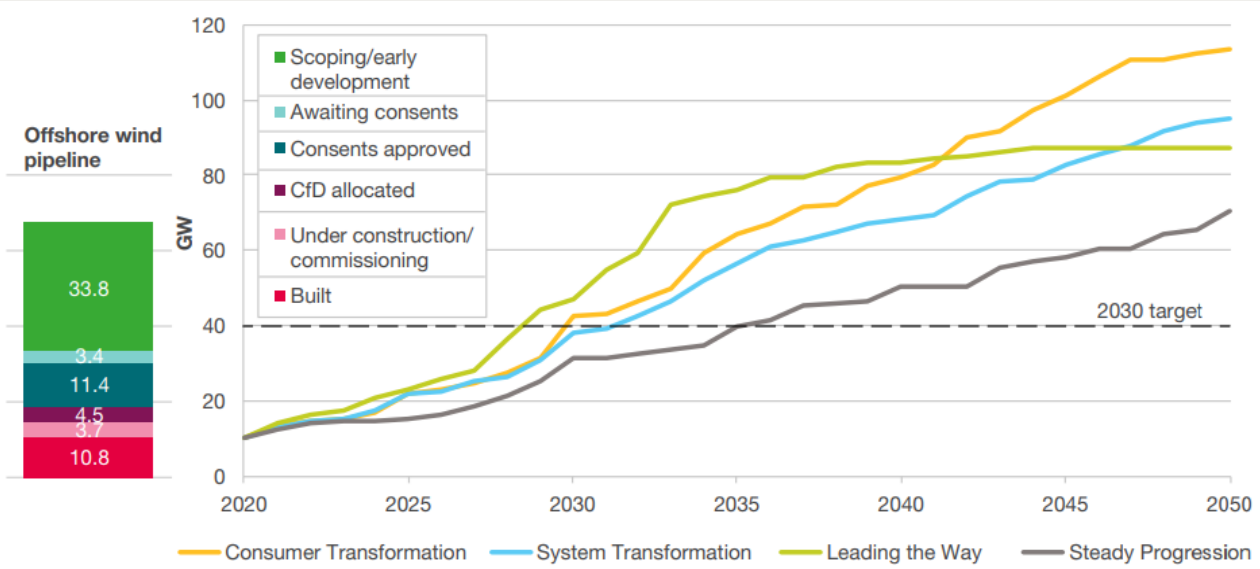
Steady Progression

Key Messages

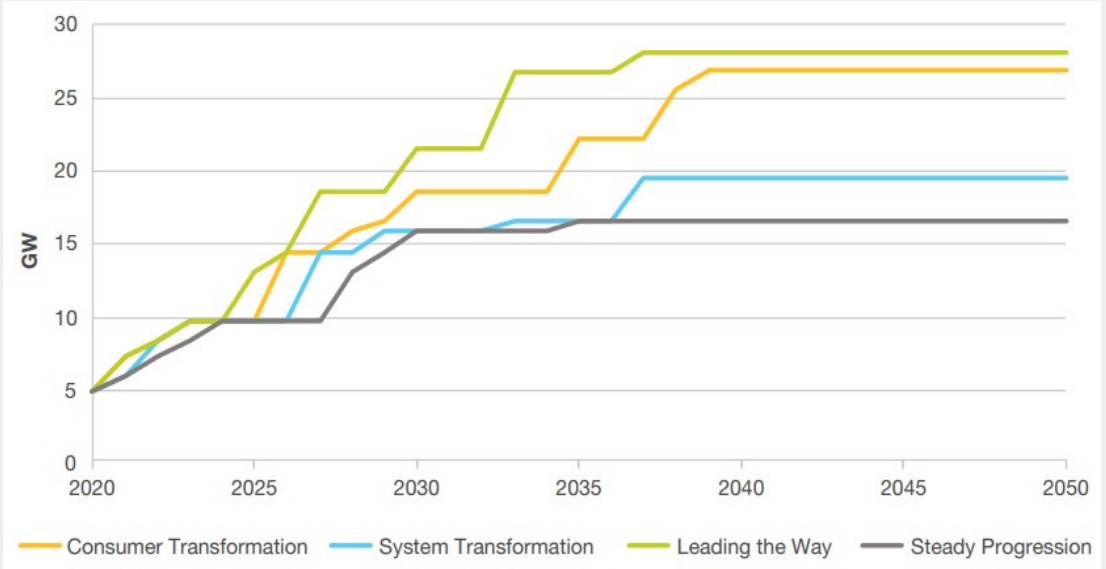
Future electricity system

- Decarbonisation.
- Decentralisation.
- Power-Electronics-Dominant.
- Significant decline in thermal power plants.

Introduction
- Capacity Roadmap from 2020-2050 – Offshore Wind & Interconnector



Capacity Roadmap for Offshore Wind



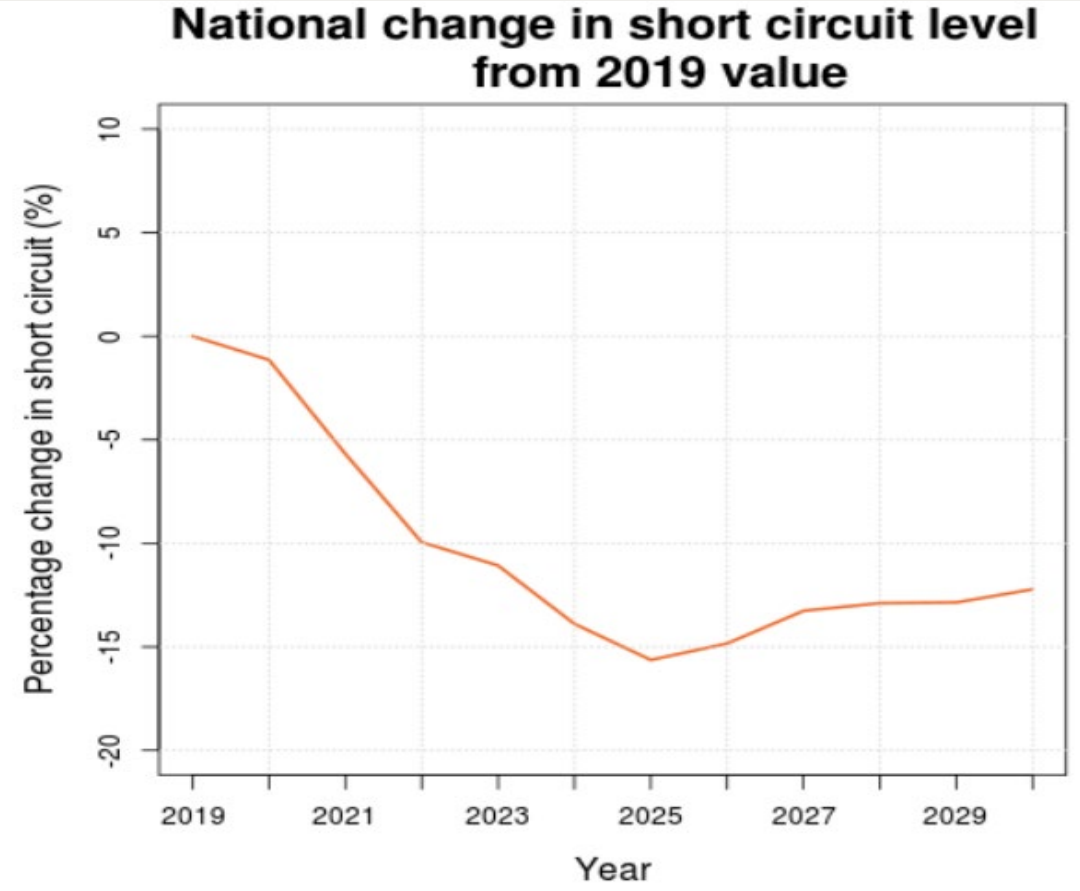
Capacity Roadmap for Interconnector

Key Messages	
Offshore Wind	**Interconnector**
• 2020: 10.5GW; 2030 target – 40GW • 2050: 113.2GW (CT); 70.7GW (SP) • NGESO's Offshore Coordination Project (In-progress) • HVDC for offshore wind integration	• 2021: 6GW; 2030 target – 18GW or more • 2050: 28.2GW (LW); 16.7GW (SP) • VSC-HVDC technology up to 1.4 GW in the UK • Concept of Multi-purpose Interconnector

Challenges

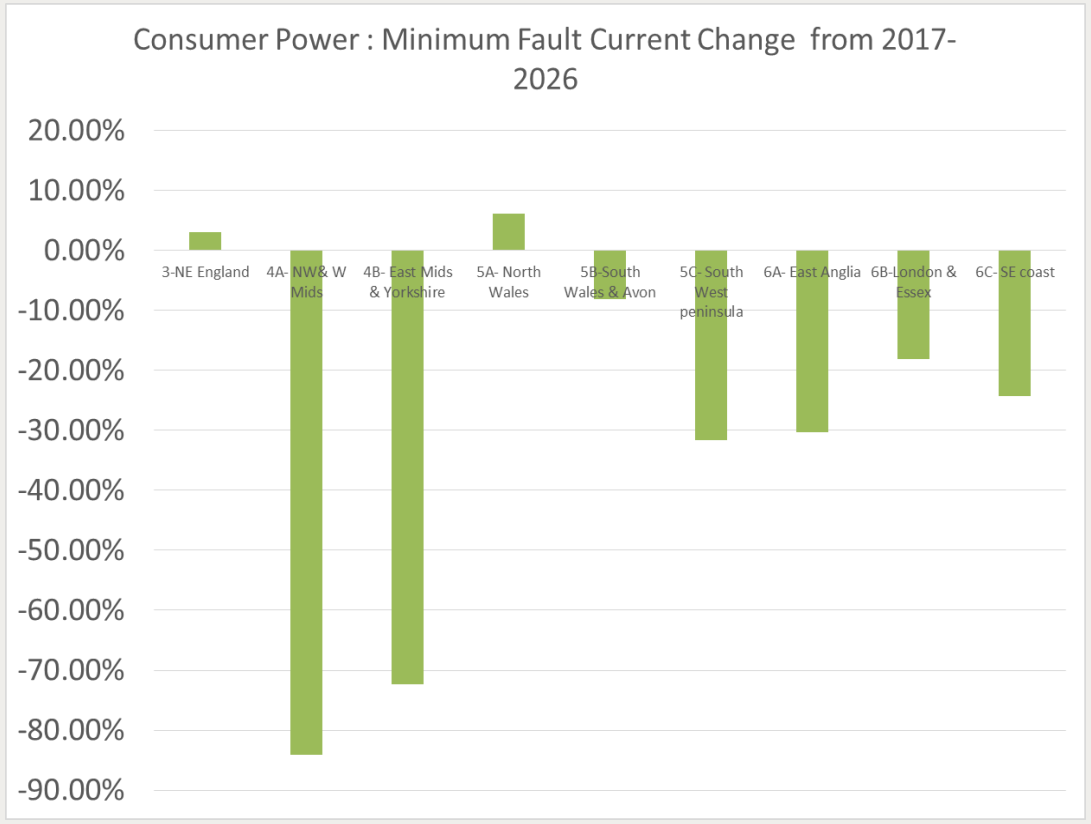
- **Low Network Inertia/SCL**
  - Protection issues
  - IBG Operation problems
  - Network Control challenges
  - Quality of Supply
- **Data management:**
  - Integration and integrity
    - ✓ Volume and storage
    - ✓ Data is not equal to information
  - **Cyber Security**
    - ✓ Information Technology - IT
    - ✓ Operational Technology - OT
- **Asset Management Issues**
  - Aging assets/shorter asset life,
  - System access and outages for replacement/maintenance
  - Knowledge and skill shortage
  - Manufacturing and delivering capability and capacity

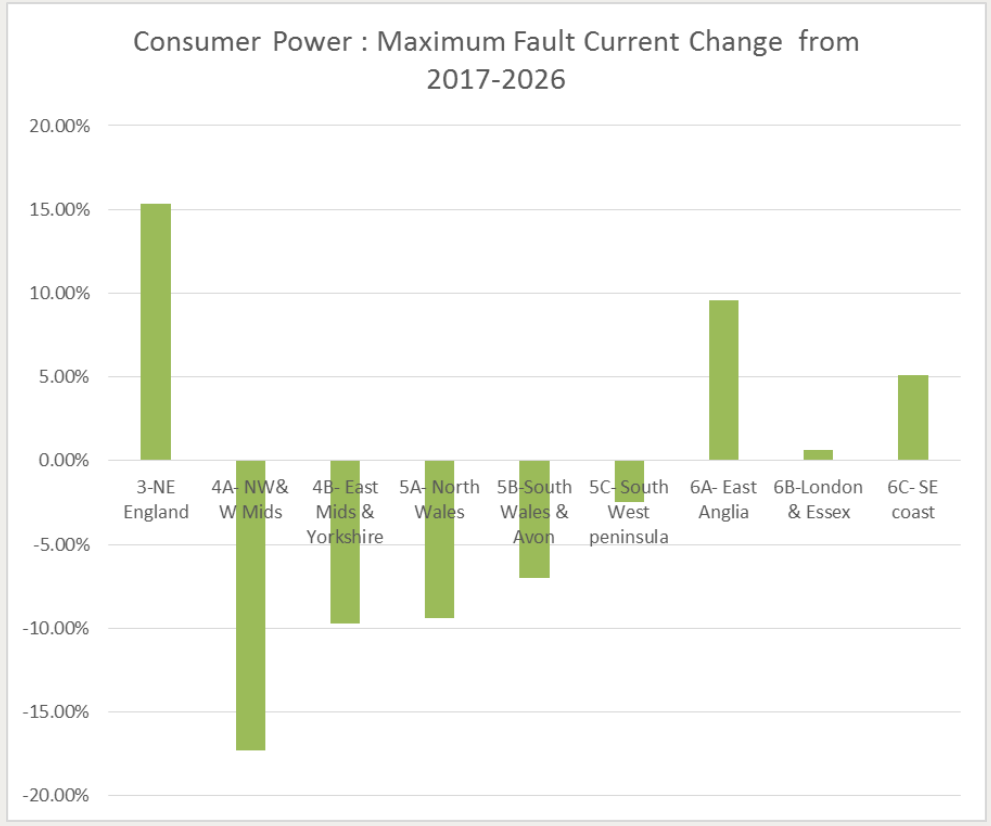
Challenges
-Impact of declining Short Circuit Levels 1/3



- **Short Circuit Level (SLC)**
  - Level declining
  - Characteristics changes: e.g. No NPS, shorter duration, SIR increase
- **Transmission Protection**
  - Some studies have identified certain back-up overcurrent and earth fault as well as distance protections may be at risk due to declining SCL.
- **Phase Locked Loop (PLL) Converter**
  - Two factors, the decline in SCL and the growth in PLL-based converters, drive potential instability risk during fault condition.
  - The PLL risk first emerges at the certain areas where there is a significant growth in PE technologies like wind and interconnectors.

Challenges
-Impact of Declining Short Circuit Levels 2/3





Main issues – impact on SIR and O/C pick up levels

Opportunity for automated measurement of F/L and trigger for setting adjustment

Challenges
- Impact of Declining Short Circuit Levels 3/3

- Fault current limited to 1.0-1.5 pu of rated inverter current
- Source impedance of inverter based generation is higher than classical synchronous generation
- The source-to-line-impedance-ratio (SIR) is a value that is used by NGET to determine whether distance elements can be used on a line.
- SIR ratios increase in relation to the growing amount of inverter-based generation
- At SIR > 30, distance protection becomes unreliable due to decreasing accuracy and increasing operating time.

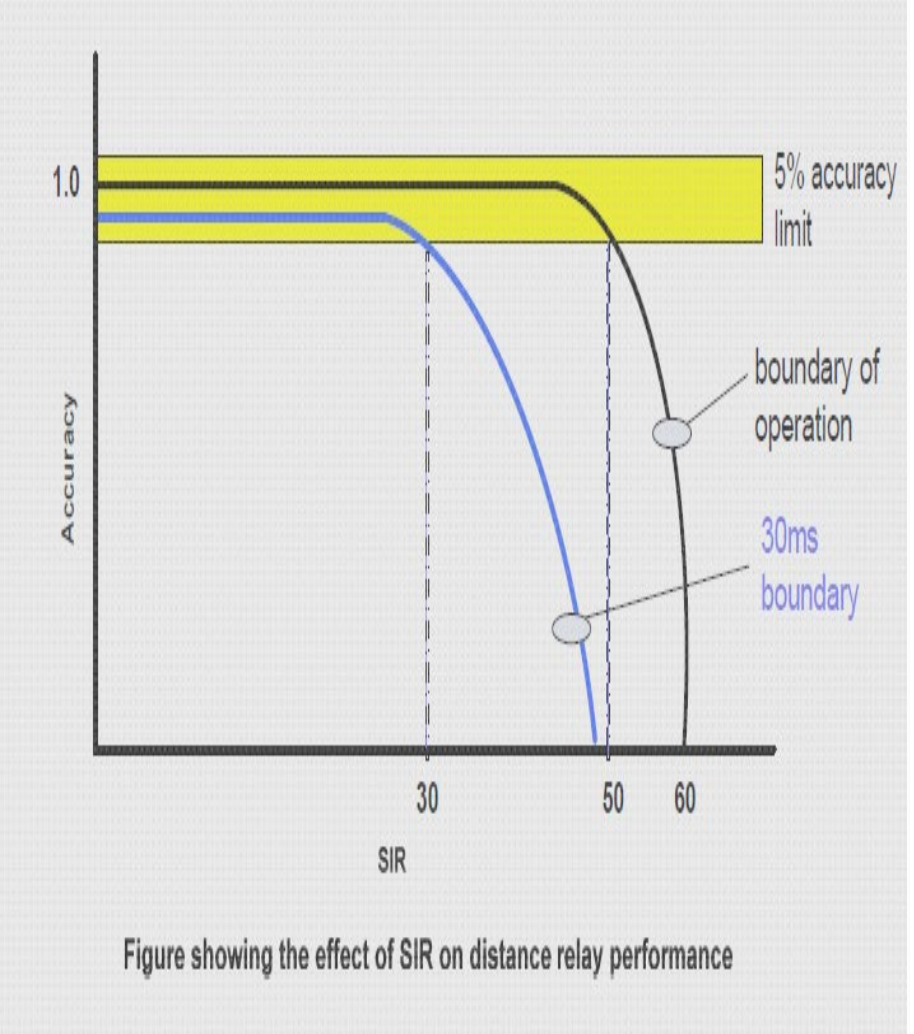
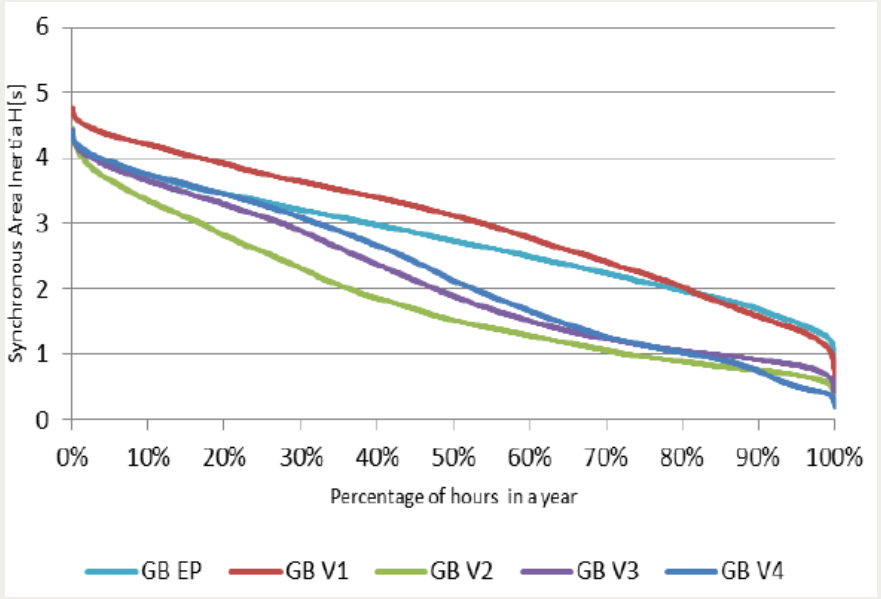


Figure showing the effect of SIR on distance relay performance

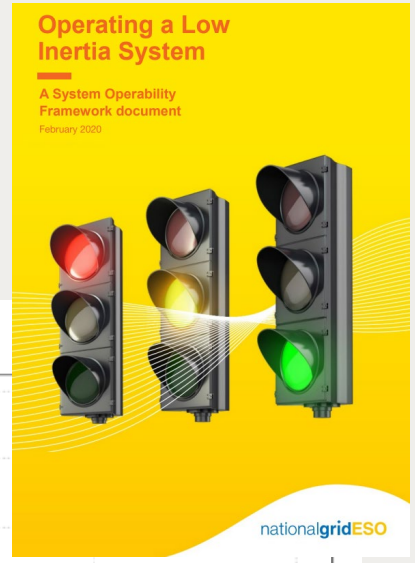
Challenges
-Impact of Low Inertia System 1/1

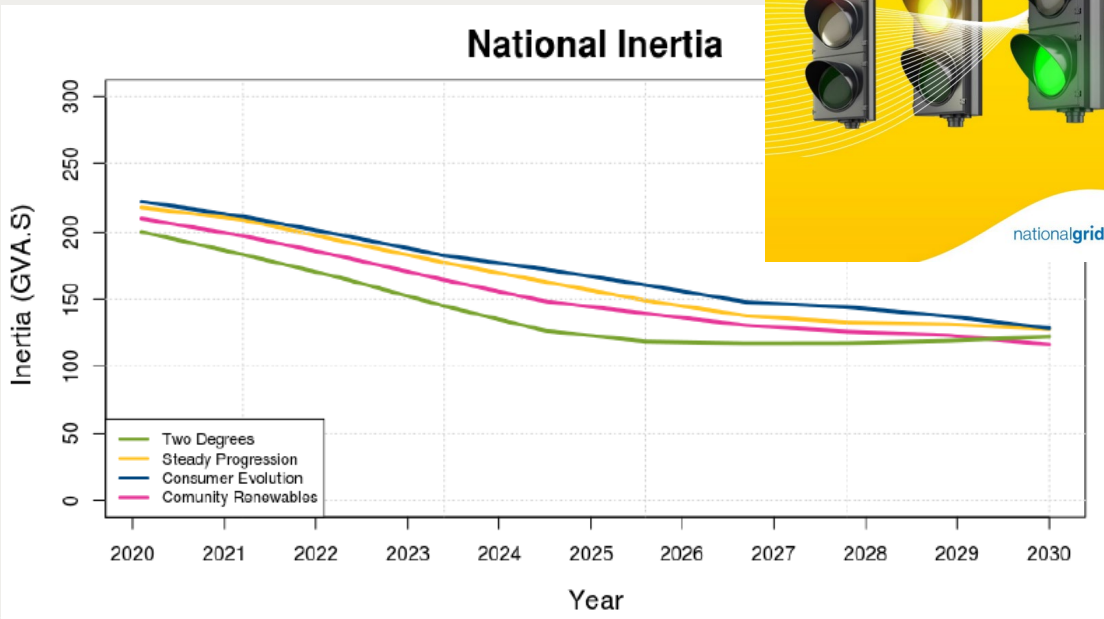
Source: ENTSOE report “Future system challenges ahead with High Penetration of PEIPS”



Inertia Development in UK based on 10-year network development plan (TYNDP)

- **Operability Risks on Low Inertia**
  - ROCOF changes
  - Fast Frequency Response
  - “Loss of Main” Tripping
  - Low Frequency Demand Disconnection (LFDD)
  - Stability





Challenges
- Cyber Security 1/2

What is “Cyber Security”?

- Evolving concept, incl. Physical Security …
- It is about ability…
- Severe threats /damages:

Operational Cyber Security

- OT Vs IT
- Control Centres (iEMS)
- Tele-Comms :SCS/iEMS, ITT, OTS etc.
- Substations: P&C equipment
- GPS: Feeder protections, time ref etc.
- Remote Access

Development & Challenges

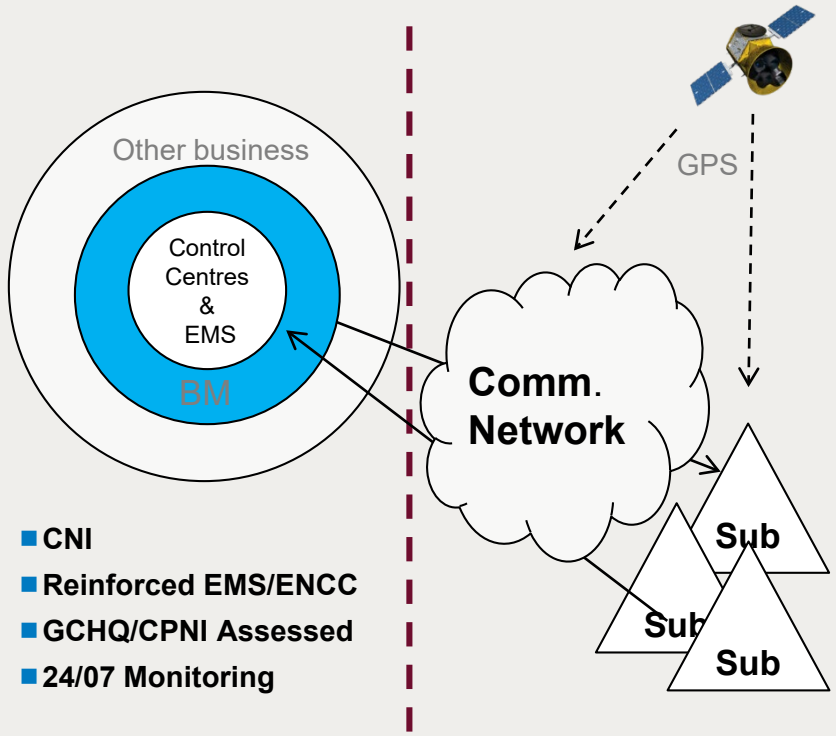
- **New/Digital Technology: Smart Grids, WAMPAC, Remote Access**
- **Standard Off-shelf products/solutions**
- **IT & OT merging,**
- **Standard protocols IEC61850 etc.**

Standards & Best Practice

- IEC 62351 /62443
- NIS directive/UK Cyber Security
- IET/IEEE guides & code of practice…
- CPNI best practice guides
- NERC-CIP (Critical Infrastructure Prot)
- Across industrial experiences
- Tools: e.g. CSET by US NIST

Challenges
- Cyber Security 2/2

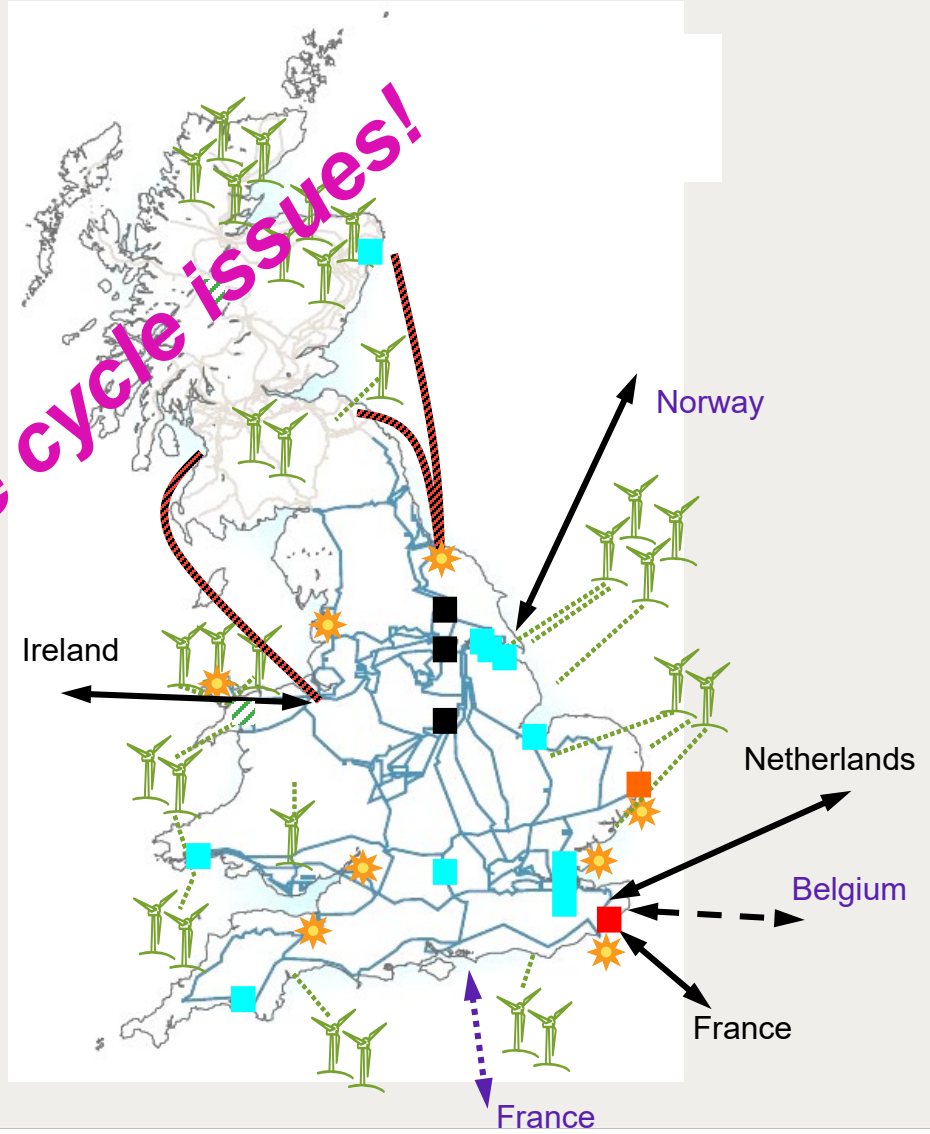
- **Risky Areas:**
  - GPS: maliciously corrupted signals
  - Uncontrolled devices: virus/malwares
  - Uncontrolled access: sites, networks, HWs/SWs
  - Insider risks: employees, contractors
- **High Impact Low Frequency – HILF?**
  - Diff risks: Control Centre Vs Subs
  - IT & OT separations
  - Comm. protocols/configurations
  - Firewalls/VPN/Remote access
- ***But Cyber Attacks happens all the time…***
  - 2017 WannaCry Ransomware Cyber Attack
  - 2015 Ukraine power grid network
  - 2014 Cyber Attack on Yahoo



Challenges

- Asset Management Issues for P&C equipment

- **A large volume: mixed technology types**
- **Shorter asset life for digital device <15 yrs**
  - 3-4 replaces during plant life (>40yrs)
  - Currently achievable replace rate 5% pa, 20 years a round of replacement
- **Long outages to install/replace**
  - Hardwired I/O interface: 6-8wks outages, high cost & risk
- **Difficult to extend substation**
  - Due to proprietary comm protocol
- **Expensive Post Delivery Support**
  - Obsolescence/parts & spares
  - Fast technology development
  - Shortage of knowledge & expertise



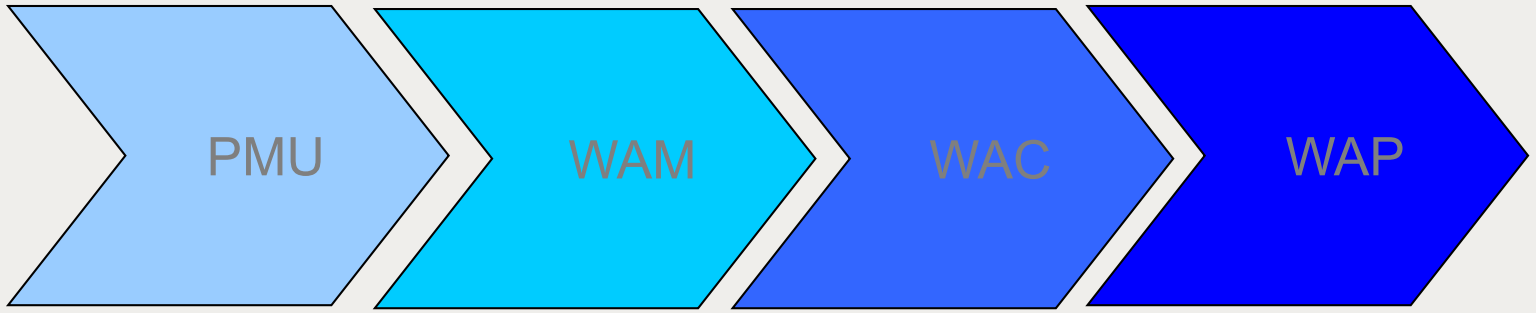
Opportunities

- **Smarter Grid Technologies**
  - Provide mitigations/solutions to the challenges
  - “Smarter” rather than “Smart”!
- **Smarter Grid Solutions/Development**
  - PUM based Wide Area Monitoring, Protection and Control (WAMPAC)
  - Smarter Cybersecurity Process and Technologies
  - IEC 61850 based digital substations
  - Smarter Asset management tools/systems
  - Emerging Smarter Grid technology/development
    - ✓ E.g. Synthetic Inertia and Grid Forming IBGs
- **Collaborations and Funding Opportunities**

Opportunities

– WAMPAC development in the UK

- **Major trials and pilot schemes in the UK since 2015**
  - Humber SmartZone
  - VISOR
  - EFCC



Opportunities

– Smarter Transmission (WAMPAC) Roadmap

WAMS

- ❑ Wide Area Monitoring Scheme
- ➢ System Awareness
- ➢ SCADA data, PMUs
- ➢ Validation of network models
- ➢ Weather data

RAS

- ❑ Remedial Action Schemes
- ➢ Monitoring & Automation
- ➢ Proactive control measures
- ➢ Run back, load shedding
- ➢ Manage thermal stability

CMS

- ❑ Congestion Management Scheme
- ➢ Monitors circuit thermal ratings
- ➢ Consider generator run back
- ➢ Weather data
- ➢ Dynamic rating

SIPS

- ❑ System Integrity Protection Systems
- ➢ Manage transient stability
- ➢ Enhanced OTS - Use WAMS to arm
- ➢ Co-ordinated LFDD/”LoM” protection

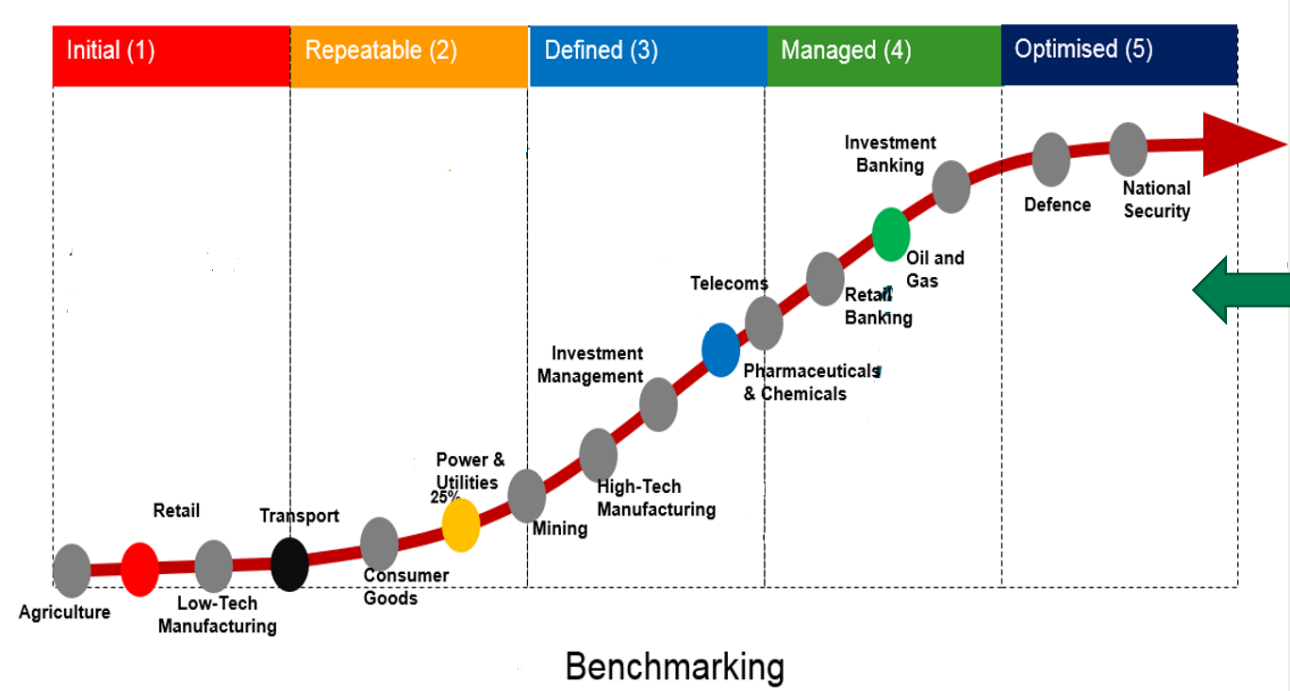
Opportunities
– WAM (DSM)

- **Drivers**
  - Low SCL/network inertia challenges
  - Greater volatility due to renewable generation and FACTS applications
  - greater use of active control & automation
  - The system is likely operating nearer stability limits and with
- **Dynamic System Monitoring (DSM) becomes increasingly important**
  - STPC 027-1 DSM requirements
- **DSM - key enabler for enhanced asset utilisation and network operation**
  - Dynamic ratings,
  - System stability management,
  - Wide area voltage control -> intelligent network automation
  - Risk Assessment

Opportunities
- Cybersecurity Strategy: Identify, Detect, Protection, Report & Response

Strategy & Process	•A suite of Policy/Specs based on NIS/CIP •Business Continuity and Disaster Recovery Plan •Site Management & Tech Assurance Process •Cyber Asset Inventory
Secured & Controlled Technology/Devices	•Compliance (e.g. IEC 62351/IEC62443, Regulations) •RBAC – Role Based Access Control + Hardening •Intrusion Monitoring & Detection Devices: IDS + IPD •Testing facilities, Anti-Virus/patch management
Removal of GPS Dependency	•Non GPS Feeder Protection •Resilient time ref, e.g. IEEE1588
Collaboration & Engagement	•Cyber Security Culture •IT& OT + all Stakeholders •Government (Ofgem), Tech bodies (CIGRE/IEC), Industry •R&D + Benchmarking

Opportunities
-Cyber Security Approach: Maturity based Vs Risk Based



❑ **Maturity based**

Pros:

- Reference to peers and other Industries
- Maturity level relatively easy to measure

Cons:

- No direct management of cyber risks
- Lack of drivers for specific measures
- Lack of direction for deployment of tools and technologies

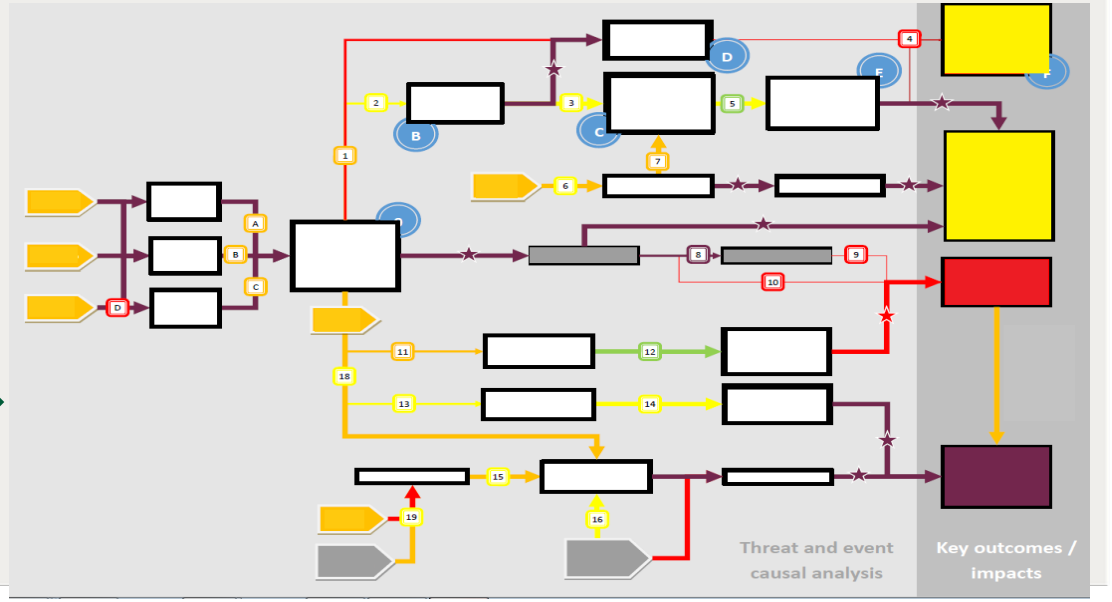
❑ **Risk Based: Likelihood + Impact + controls**

Pros:

- Active risk management
- Agreed risk level with stakeholders
- Requirement

Cons:

- Labour intensive



Opportunities
- Rollout of IEC61850 based P&C Systems

❑ **Key Benefits – *Whole Lifecycle***

➢ **Station Bus**

- Vender Interoperability for **extension**

➢ **SBS**

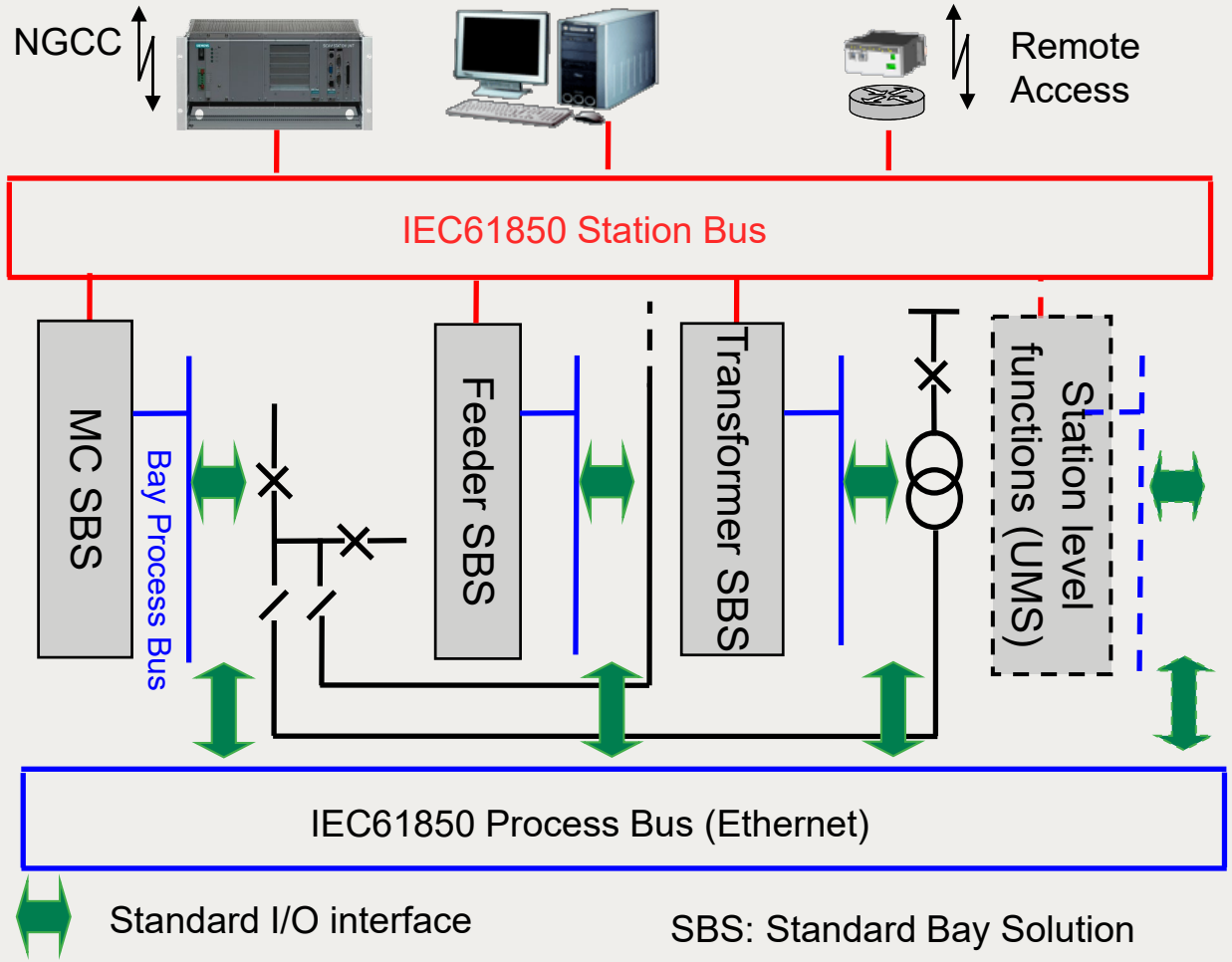
- **Proven designs** to reduce risk, cost & delivery time,

➢ **Process Bus**

- **"Plug & Play"** quick install/replacement
- Vender Interoperability & Inter-changeability to efficiently manage obsolescence & **support cost**
- Fibre optical connections to reduce EMC requirements & **Safer**

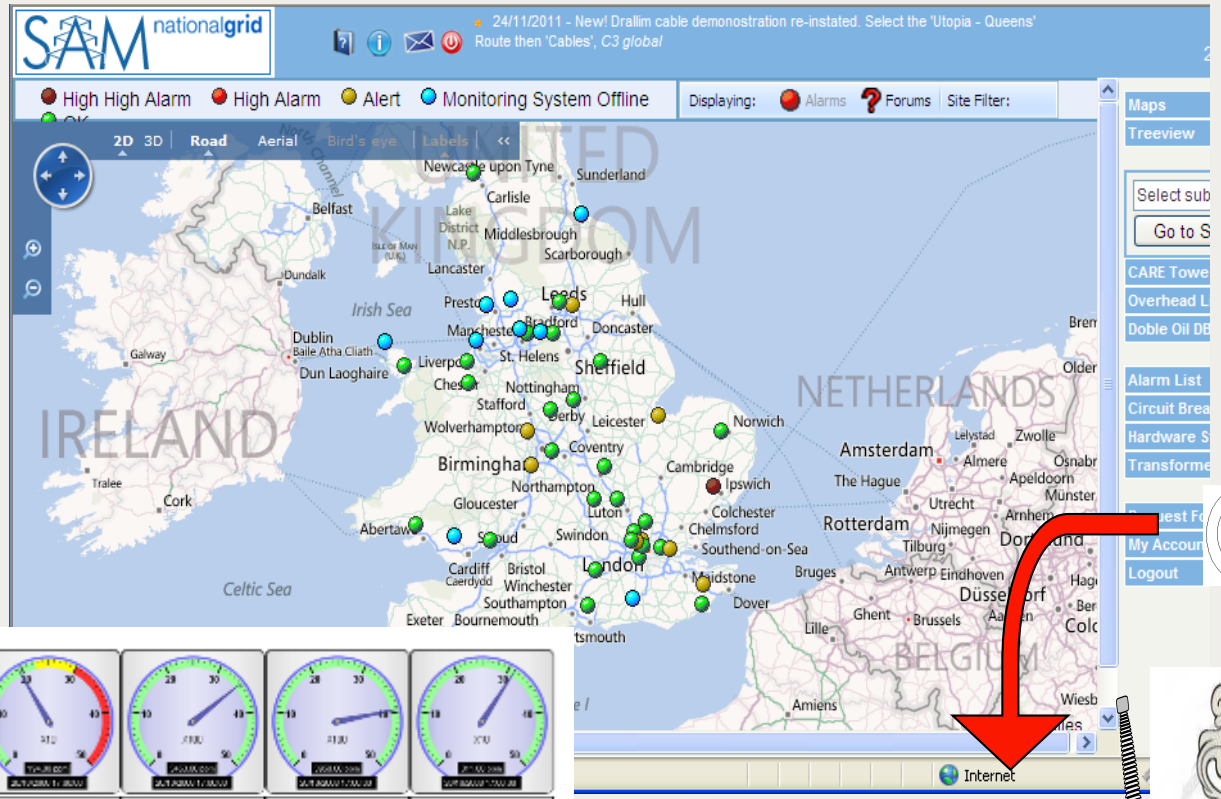
➢ **Standard I/O**

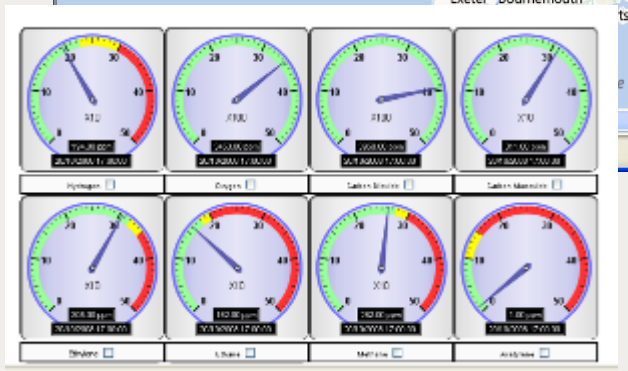
- Future proof
- **Reduce outage period**

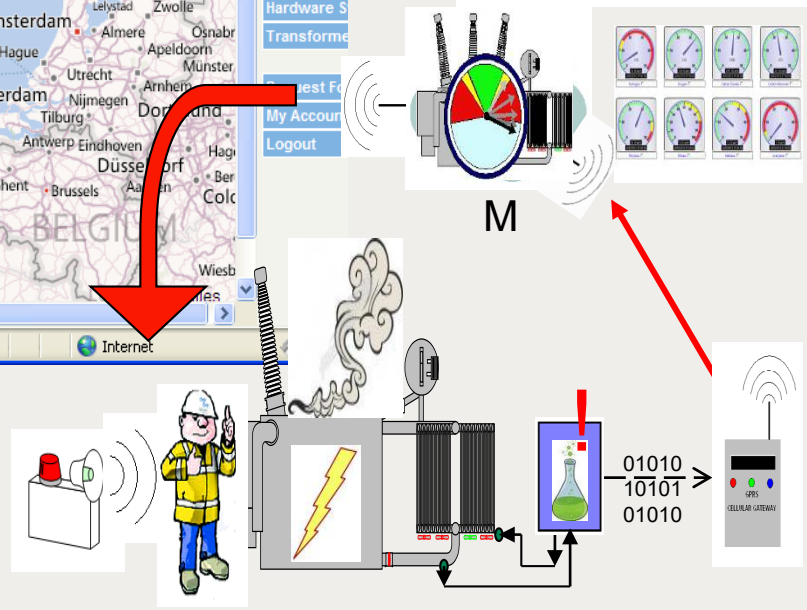


-AS^3 Architecture for Sub Secondary Systems

Opportunities - Smarter Asset Management (SAM)
-A holistic method to share data across business







- Quick visual check on assets
- Mobilise & Visualise live data
- DGA, SF6, PD Monitoring
- Maintenance/business planning

Opportunities
-Emerging Smarter Grid Technology/Development

- **Synthetic Inertia**
  - ✓ Wind generations to support fast frequency control
  - ✓ Synch Condenser to provide inertia support (Phoenix NIC project) (www.spenergynetworks.co.uk/pages/phoenix.aspx#tablist1-panel1)
  - ✓ Inertia and SCL monitoring
- **Grid Forming IBGs**
  - ✓ Blackstart functions
  - ✓ High V and Long FRT
- **Digital Twin**
  - ✓ *Part of WAMPAC?*
- **Travelling Wave Protection**
  - ✓ Resilience to low SCL/inertia
  - ✓ High telecom requirements
  - ✓ Further development needs: Noise filtering, cross-zero point issues
- **Auto Protection Co-ordination studies**
  - ✓ IBG and network Modelling
  - ✓ Relay models
  - ✓ Data inputs
- **MPLS telecom network**
  - ✓ IEC61850 apps on WAN

Opportunities
-Collaborations and Funding

- ***Collaborations***
  - International: CIGRE, IEEE, IEC, IET such as
    - ✓ CIGRE JWG B5/C4 -61
    - ✓ IEEE Relay Group
    - ✓ IEC TC57 WG10, WG19…
  - Regional/National: e.g. Entso-e, NERC/FERC, ENA,
  - Organizational: i.e. Utilities, Universities, consultancy companies, manufacturers
- ***Funding***
  - Regional : e.g. Entso-e, NERC/FERC
  - National/Organizational: e.g. ESPRC(UK), UK Ofgem SIF (£490m/5 years), NIA (UK utilities ~1% Revenue),

Golden Era!

Summary/Q&A

- **Summary**
  - Global drivers for climate changes
  - Hugh challenges to power Industry: unprecedented transitions
  - Smarter Grid technologies could provide solutions/mitigations
  - Much research & development are needed
  - “Golden era” for collaborations and funding
    - ✓ Make most of it!
- **Q&A**
  - Any questions?

Thank you for listening!