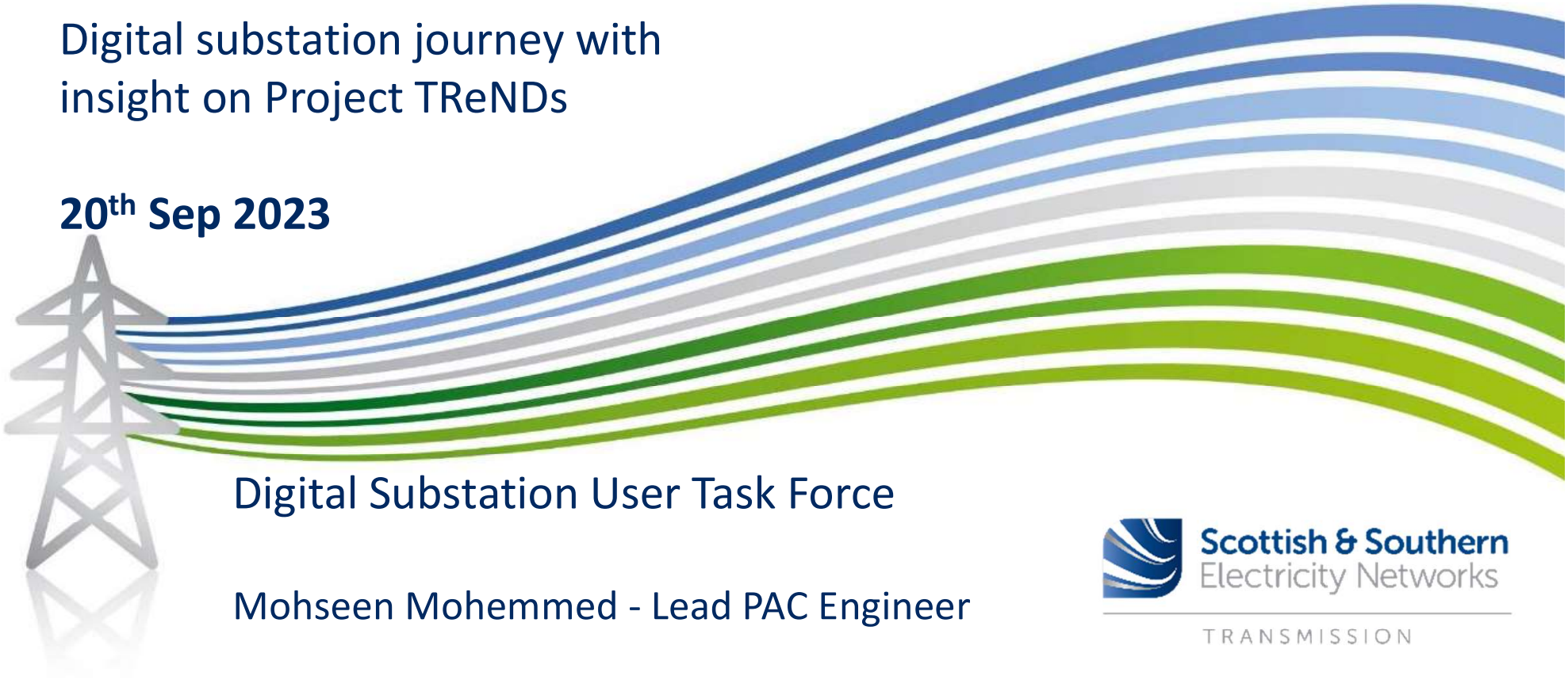
SSEN Transmission

Digital substation journey with insight on Project TReNDs

20th Sep 2023



Digital Substation User Task Force

Mohseen Mohemmed - Lead PAC Engineer

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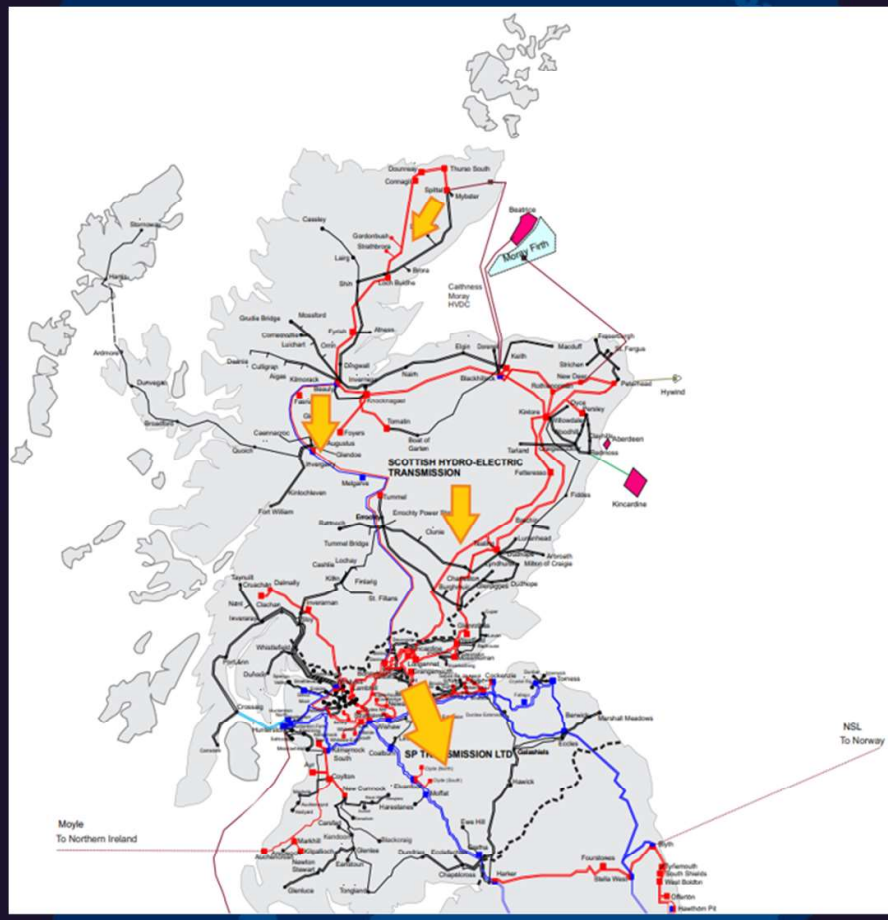
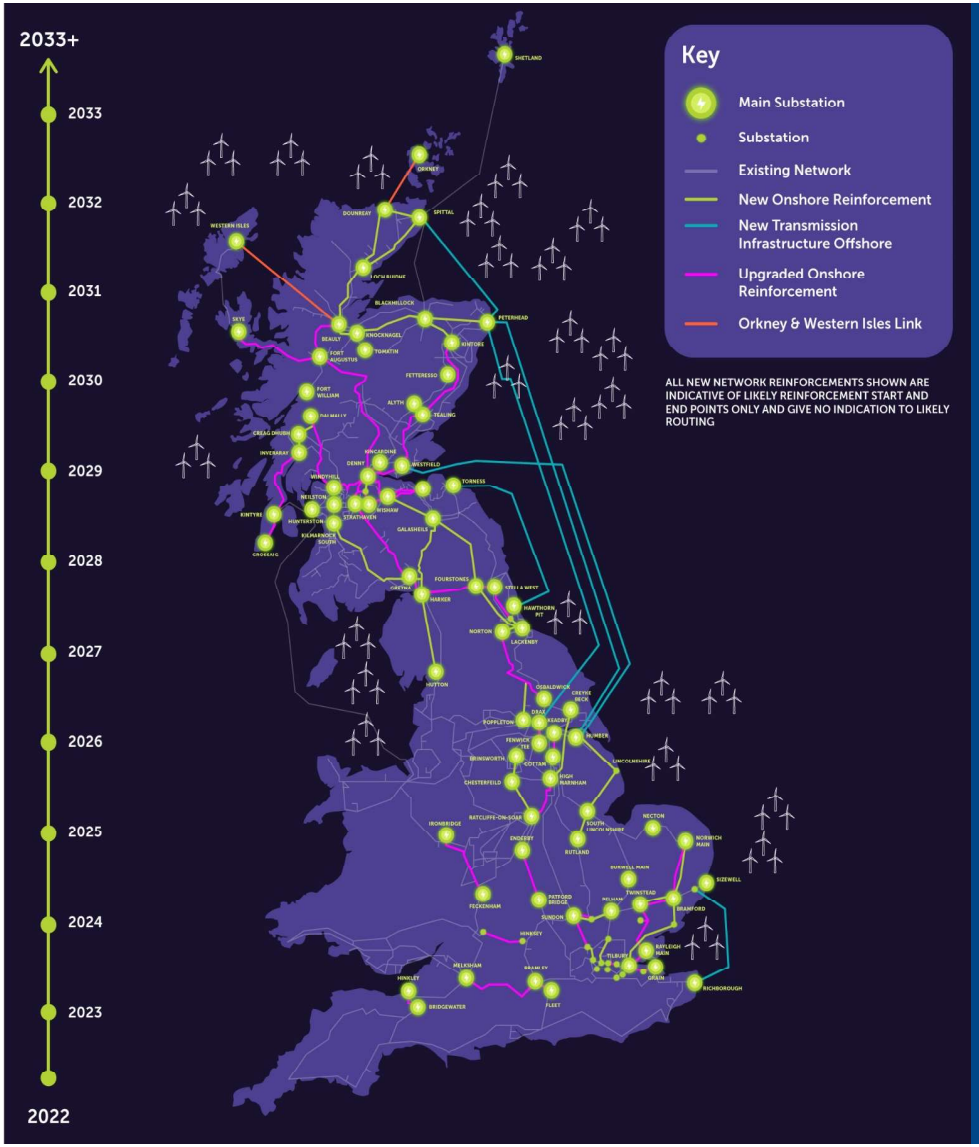
Current Grid

Great Britain





Future of the Grid

Great Britain

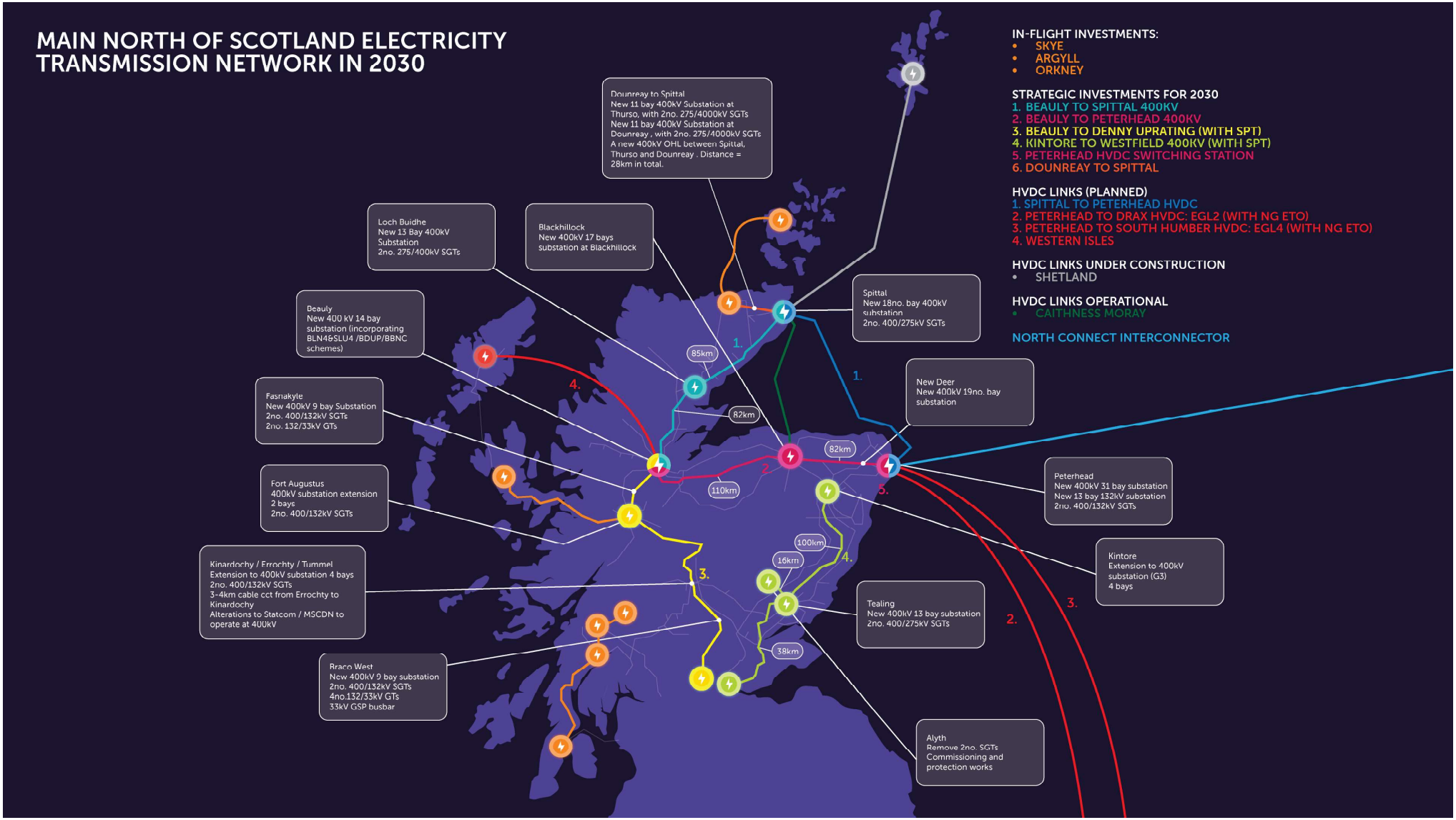
- Offshore Wind
  - Current Capacity
    11.2GW
  - Ambition
    50GW connected by 2030
- HND delivers 23GW of this and 11GW of this is located in Scotland
- The Pathway to 2030 Holistic Network Design | National Grid ESO

Future of the Grid

North of Scotland

- In-flight Investments
- Pathway to 2030 Investments

- Areas where projects targeting oil and gas decarbonisation will be considered
- Scotwind Option Agreements
- Scotwind Plan Options
- Exclusions - Areas where no INTOG projects will be considered
- New Infrastructure (Routes shown here are for illustrative purposes)
- Upgrade/Replacement of Existing Infrastructure
- Existing Network


MAIN NORTH OF SCOTLAND ELECTRICITY TRANSMISSION NETWORK IN 2030
IN-FLIGHT INVESTMENTS:
• SKYE
• ARGYLL
• ORKNEY
STRATEGIC INVESTMENTS FOR 2030
1. BEAULY TO SPITTAL 400KV
2. BEAULY TO PETERHEAD 400KV
3. BEAULY TO DENNY UPRATING (WITH SPT)
4. KINTORE TO WESTFIELD 400KV (WITH SPT)
5. PETERHEAD HVDC SWITCHING STATION
6. DOUNREAY TO SPITTAL
HVDC LINKS (PLANNED)
1. SPITTAL TO PETERHEAD HVDC
2. PETERHEAD TO DRAX HVDC: EGL2 (WITH NG ETO)
3. PETERHEAD TO SOUTH HUMBER HVDC: EGL4 (WITH NG ETO)
4. WESTERN ISLES
HVDC LINKS UNDER CONSTRUCTION
• SHETLAND
HVDC LINKS OPERATIONAL
• CAITHNESS MORAY
NORTH CONNECT INTERCONNECTOR
Dounreay to Spittal
New 11 bay 400kV Substation at Thurso, with 2no. 275/4000kV SGTs
New 11 bay 400kV Substation at Dounreay , with 2no. 275/4000kV SGTs
A new 400kV OHL between Spittal, Thurso and Dounreay . Distance = 28km in total.
Loch Buidhe
New 13 Bay 400kV Substation
2no. 275/400kV SGTs
Blackhillock
New 400kV 17 bays substation at Blackhillock
Spittal
New 18no. bay 400kV substation
2no. 400/275kV SGTs
Beauly
New 400 kV 14 bay substation (incorporating BLN4&SLU4 /BDUP/BBNC schemes)
Fasnakyle
New 400kV 9 bay Substation
2no. 400/132kV SGTs
2no. 132/33kV GTs
Fort Augustus
400kV substation extension
2 bays
2no. 400/132kV SGTs
Kinardochy / Errochty / Tummel
Extension to 400kV substation 4 bays
2no. 400/132kV SGTs
3-4km cable cct from Errochty to Kinardochy
Alterations to Statcom / MSCDN to operate at 400kV
Braco West
New 400kV 9 bay substation
2no. 400/132kV SGTs
4no.132/33kV GTs
33kV GSP busbar
New Deer
New 400kV 19no. bay substation
Peterhead
New 400kV 31 bay substation
New 13 bay 132kV substation
2no. 400/132kV SGTs
Kintore
Extension to 400kV substation (G3)
4 bays
Tealing
New 400kV 13 bay substation
2no. 400/275kV SGTs
Alyth
Remove 2no. SGTs
Commissioning and protection works
85km
82km
82km
110km
100km
16km
38km
1.
1.
2
2.
3.
3.
4.
4.
5.

Future of the Grid

Network Options Assessment

Investment to upgrade the Transmission Grid

Opportunities

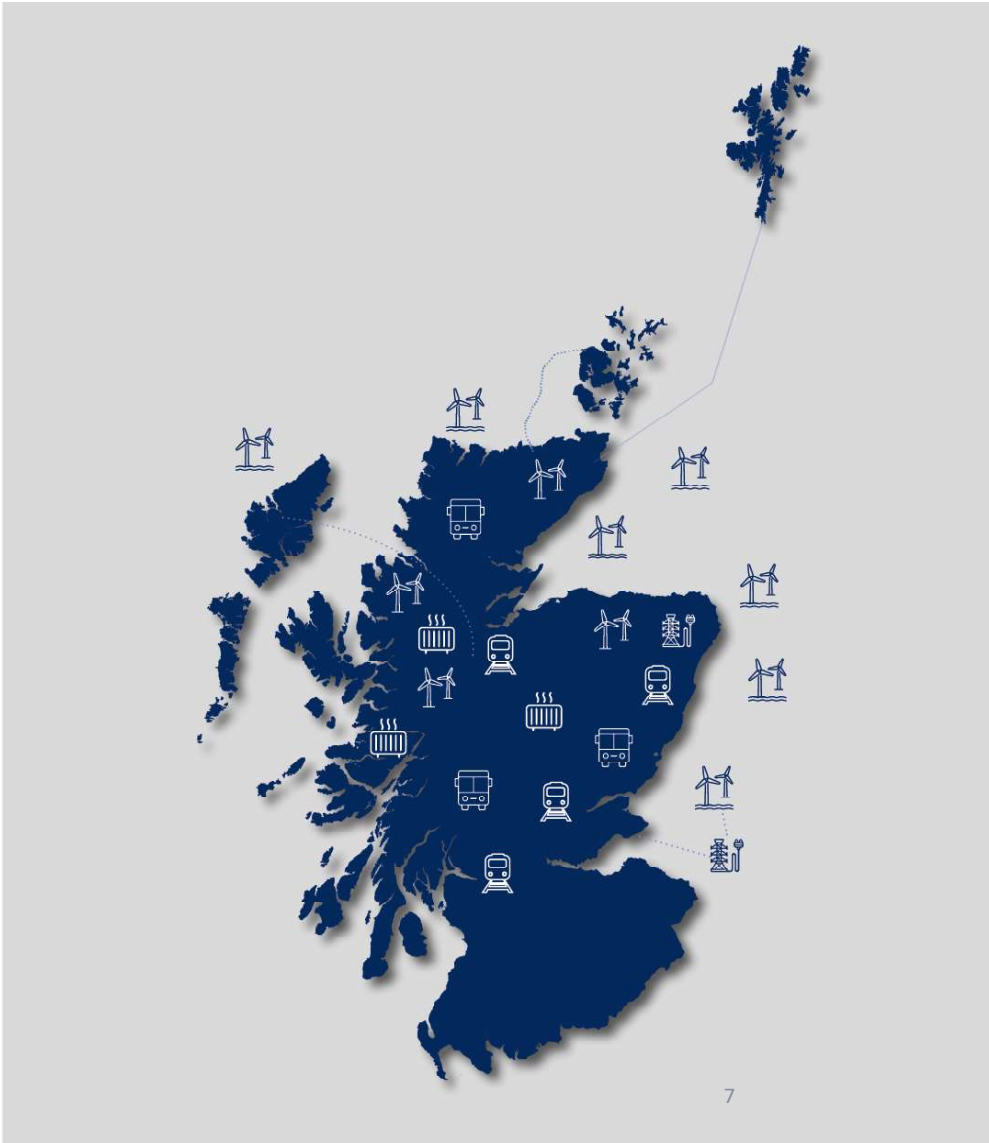
Playing a critical role in delivering UK decarbonisation

2030 Acceleration
Holistic Network Design for offshore wind - HND1

HND2
Delivery post 2030

Offshore Grid
inc. INTOG e.g. oil & gas offshore converter stations

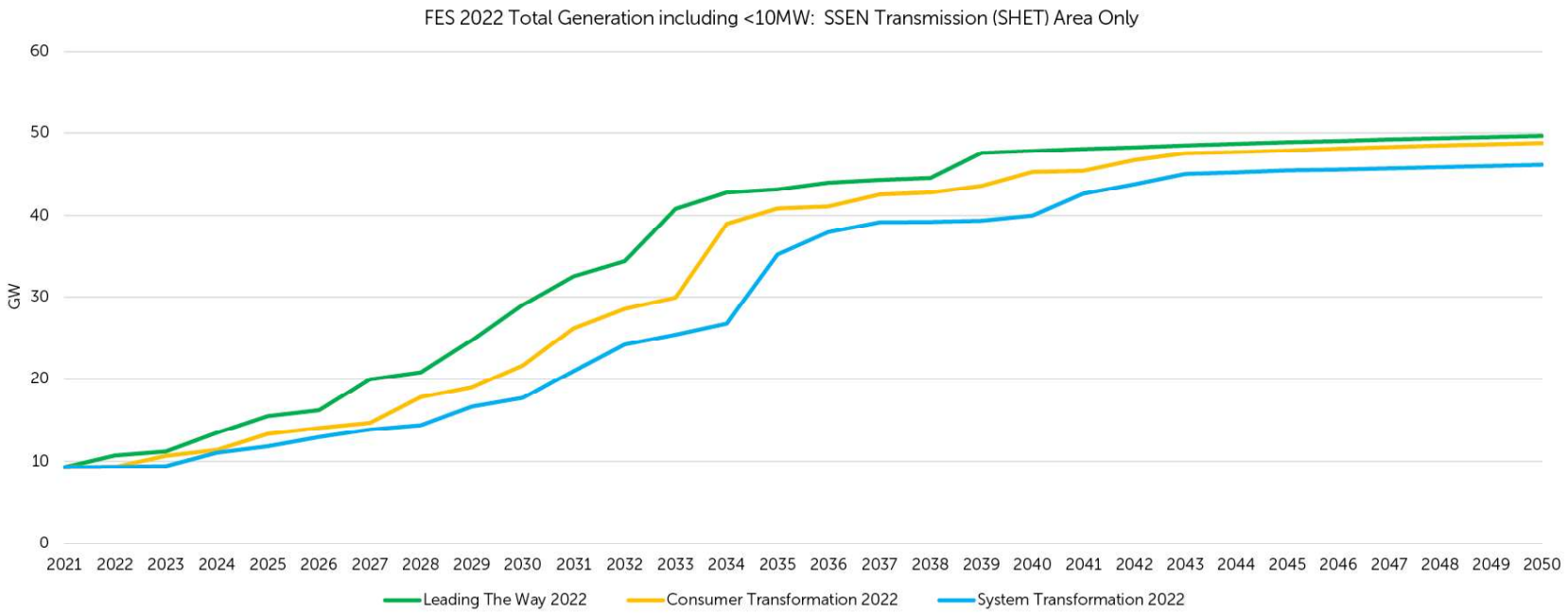
Increased Electrification
inc. railways, vehicles, heat



INTOG: Innovation and Targeted Oil & Gas

North of Scotland is a key enabler of GB's energy transition

SSEN Transmission set to deliver 10% of GB total emissions abatement required for net zero



Source: Future Energy Scenarios 2022 | National Grid ESO

Scottish Hydro-Electric Transmission (SHET) is part of SSE plc and operates under licence as SSEN Transmission

Digital Journey so far..

- Successfully energized first 4 planned IEC61850 -8-1 sites (station bus only). mid 2018. Now BaU
- Integration of standard protection IED configurations
- Full interoperability delivered. First of its kind to achieve in U.K

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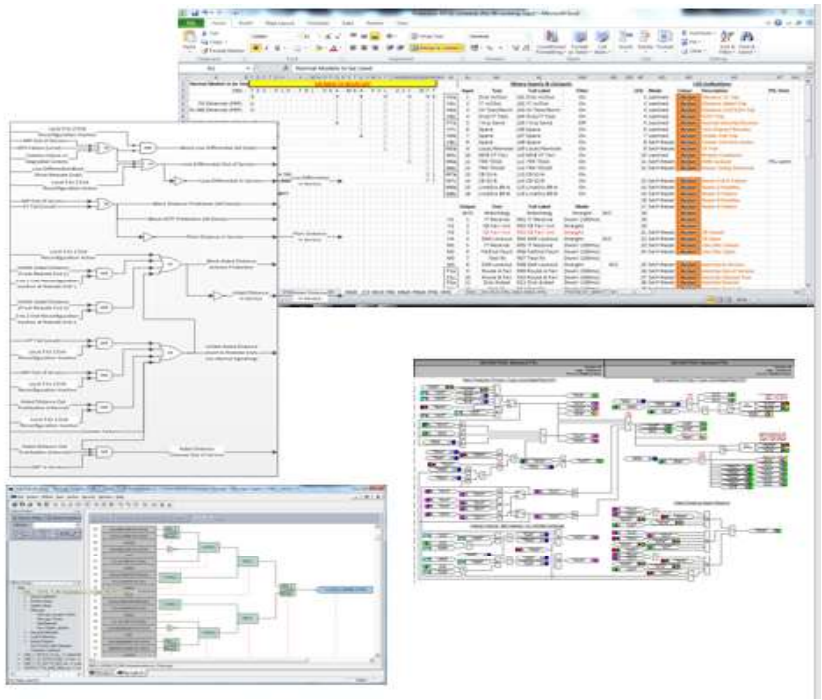
Digital Journey so far..

- Standard configurations rolled out across the sites
- First implementation of innovative communication Architecture for SSEN
- PRP and PTP deployed
- Integration of standard protection IED configurations



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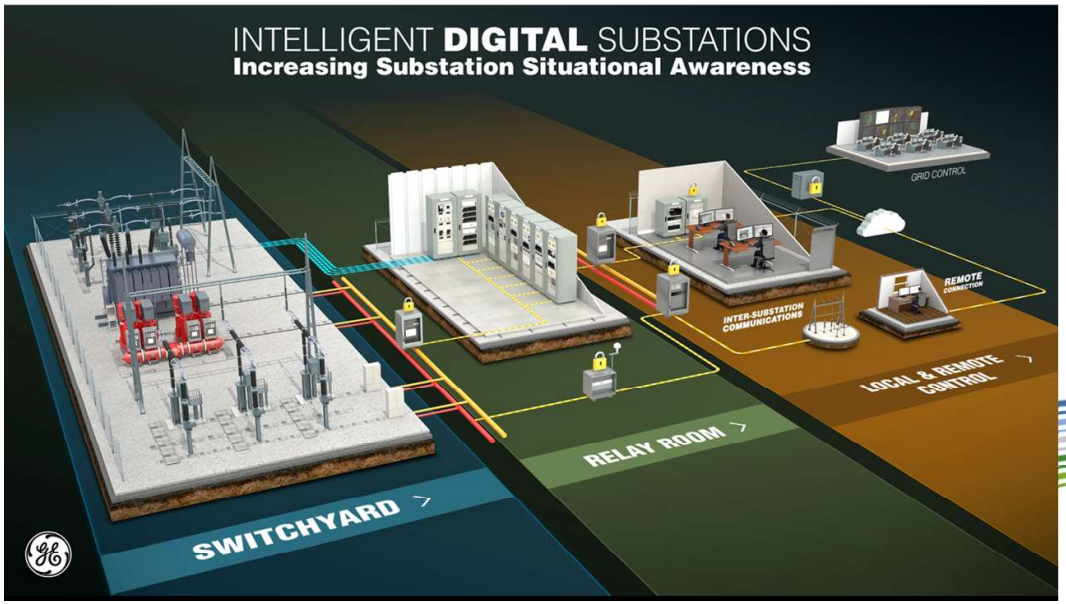
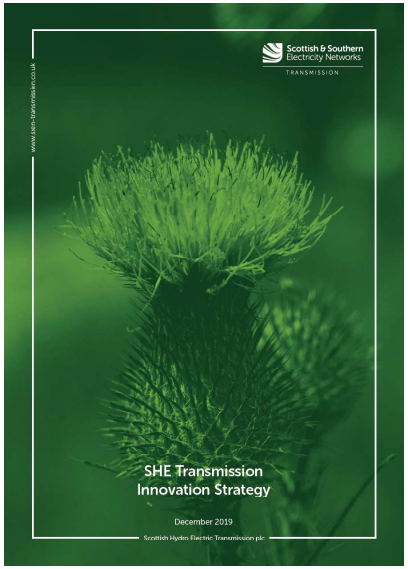
Digital Substations

What is the Vision

- A substation where information & control signals are transferred digitally (using fibres)
- Operational Benefits
  - Improved Safety
  - Improved Data
  - Risk Based Asset Management
- Project Benefits
  - CAPEX savings
  - Faster Construction
  - Increased Standardisation





Sector Leading Efficiency

Integrated approach to whole life development and operation, using risk-based engineering to deliver value.

- Supply Chain Efficiencies
- Modernising Our Network
- Network Monitoring & Operations

- Aligns with our key Innovation Strategy
- Provides TOTEX benefits

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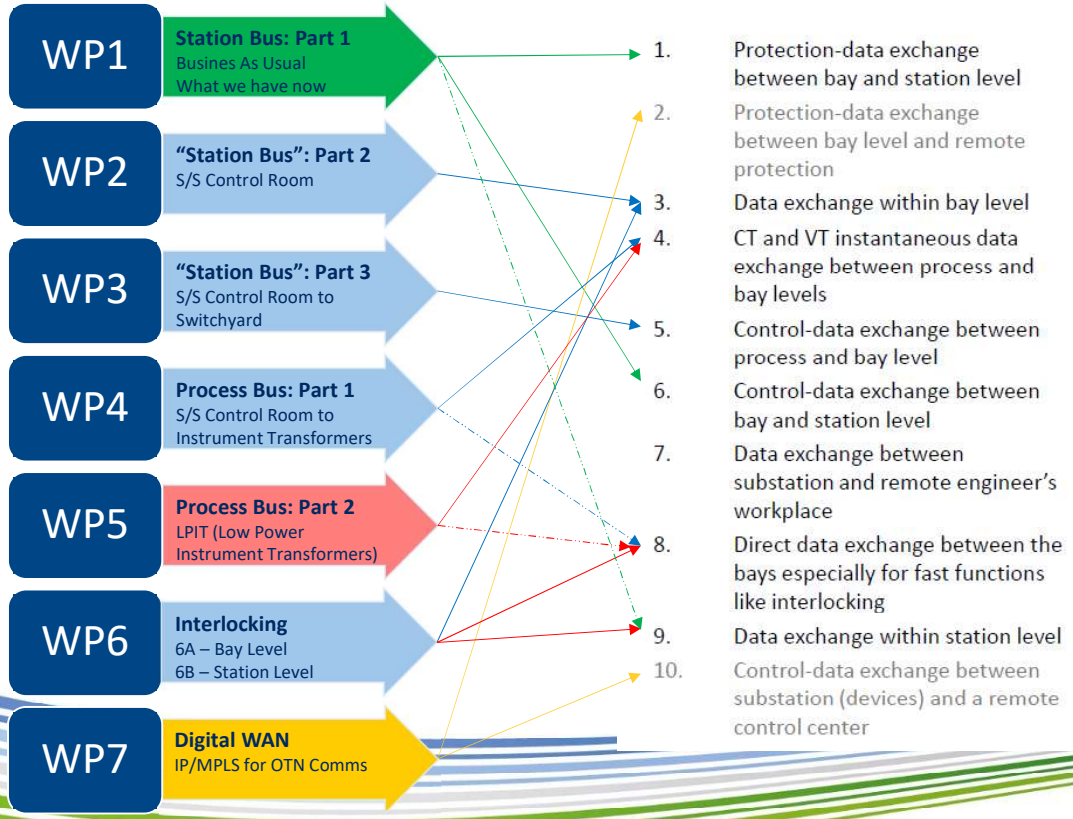
Digital Substations

Project TReNDS

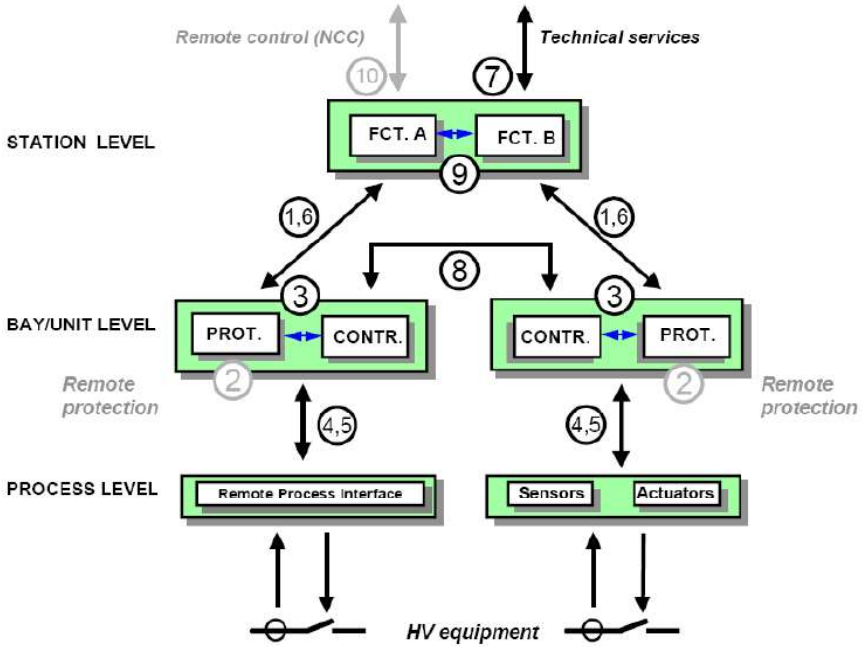
- SSEN Transmission's Digital substation development aka Project TReNDS (**Tr**ansmission **N**etwork **D**igital **S**ubstation) is of strategic importance and will enable the modernisation of our network and build a Network for Net Zero
- Project TReNDS aims to expand the Digital Substation to the next level by digitising at the source (within the switchyard) and providing fibre-based Ethernet signals all the way to the control room.
- SSEN will develop and deploy GOOSE messaging and Sampled Values (SV) for the first time on a substation wide scale
- Produced a Functional Requirement Document to work with supplier to identify the latest technology
- Utilise lessons learned from the Substation Improvement Programme, adopting the same top-down engineering philosophy.
- Identified 2 lead projects for fully digital substation implementation with energisation in Q4 2025

Digital Substations

Our Digital Substation Approach



BS EN 61850 Communication Model



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Digital Substations

Our Digital Substation Approach

WP1 — **Station Bus: Part 1**
Busines As Usual
What we have now

WP2

WP3

WP4

WP5

WP6

WP7

- First deployments on Caithness-Moray Projects
- Implementation Style
  - Developed on Live Projects
  - No advanced work or trial implementation
  - Enforced rapid development of standardised PAC solutions
- Now Business as Usual for ALL SSEN Transmission sites
  - SCS Optimisation Project improved the BS EN 61850 standardisation (recently completed)
- Cybersecurity not inherently “baked in”

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Digital Substations

Our Digital Substation Approach

WP1

WP2 — **"Station Bus": Part 2** S/S Control Room

WP3

WP4

WP5

WP6

WP7

- WP2 will remove wiring between IEDs within the Control Room
  - Introduction of GOOSE messaging between IEDs
  - Partial reduction of Panel Construction & Installation time
  - Development of strategy for operation, control, isolation and testing
- OFGEM Technology Readiness Level (TRL)
  - TRL6 Available but limited deployment (Now)
  - TRL8 Ready for BAU (Upon Completion)
- Opportunity to "bake-in" cybersecurity measures at the initial design

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Digital Substations

Our Digital Substation Approach

WP1

WP2

WP3 — **"Station Bus": Part 3** S/S Control Room to Switchyard

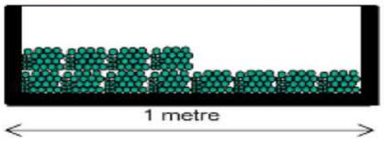
WP4

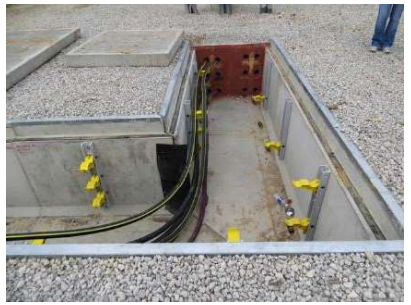
WP5

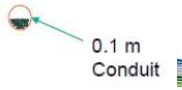
WP6

WP7

- WP3 will remove DC wiring between Control Room and Switchyard Equipment
  - Further development of GOOSE messaging between IEDs
  - Significant reduction of Panel Construction & Installation time
  - Reduce number of panels ("remove not move")
  - Development of standardised outdoor kiosk (AIS) with integrated IEDs (e.g. Switchgear Control Units)
  - Significantly reduce multi-cores and wiring time
  - Further development of strategy for operation, control, isolation and testing
- OFGEM Technology Readiness Level (TRL)
  - TRL6 Available but limited deployment (Now)
  - TRL8 Ready for BAU (Upon Completion)
- Opportunity to "bake-in" cybersecurity measures at the initial design







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Digital Substations

Our Digital Substation Approach

WP1

WP2

WP3

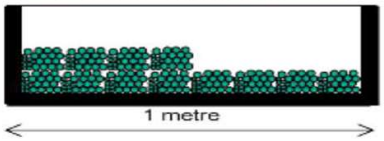
WP4 — **Process Bus: Part 1** S/S Control Room to Instrument Transformers

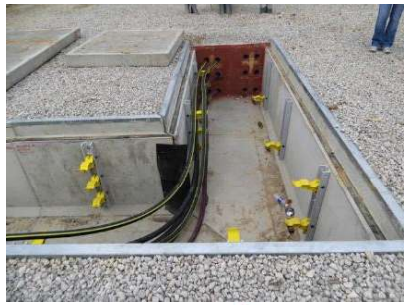
WP5

WP6

WP7

- WP4 will remove AC wiring between Control Room and Switchyard Equipment
  - Introduction of Sampled Values messaging between IEDs
  - Enhancement of standardised outdoor kiosk (AIS) with integrated IEDs (e.g. Analogue Merging Units)
  - Final reduction of multi-cores and wiring time
  - Further development of strategy for operation, control, isolation and testing
- OFGEM Technology Readiness Level (TRL)
  - TRL6 Available but limited deployment (Now)
  - TRL8 Ready for BAU (Upon Completion)





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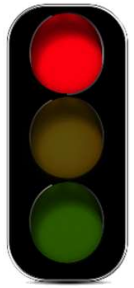
Digital Substations

Our Digital Substation Approach



WP1

WP2

WP3

WP4

WP5 — **Process Bus: Part 2** LPIT (Low Power Instrument Transformers)

WP6

WP7

- WP5 not chosen for initial Digital Substation Development
  - Cost benefit is questionable
  - Maturity of LPITs and installation *Contractors* is questionable
  - Testing difficulties – no possibility for "secondary" injection
  - Regulatory issues – not accepted for Settlement Metering
- LPITs are already installed in the SSEN Transmission network (trial purposes only)

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Digital Substations

Our Digital Substation Approach

WP1

WP2

WP3

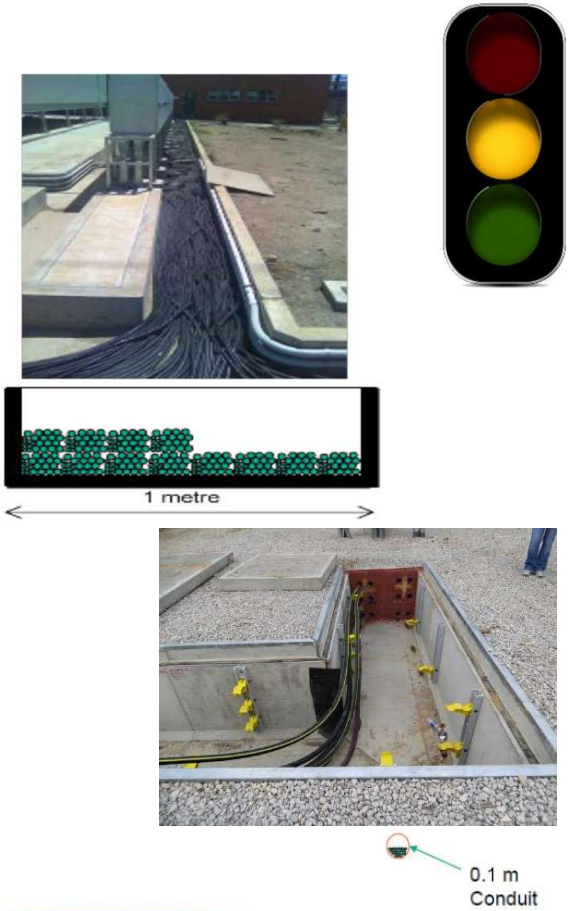
WP4

WP5

WP6 — **Interlocking**
6A – Bay Level
6B – Station Level

WP7

- WP6A is improving our knowledge and acceptance of bay level interlocking
  - Usually an available function embedded within SCU
  - Will be implemented in parallel with standard electrical interlocking (Safety Critical requirement)
  - Development of strategy for operation, control, isolation and testing



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Digital Substations

Timescales / Plan

- Provisional Programme for Research Work:
  - Initial Research work commenced July 2022 on WP2
  - Initial Research work on WP3, WP4 and WP6A - Dec 2022
- Detailed Design Work:
  - Detailed Design work planned March 2023 (WP2, WP3, WP4 and WP6A)
  - Delayed start due to supply chain issues with IED manufactuers
  - Started Mid May 2023 in progress now
- Specification Roll-out:
  - Completed by Q1 2024 for WP2, WP3, WP4 and WP6A
  - Dates might change slightly
- Two Delivery Sites already Identified:
  - ITT due for release Oct 2023
  - Contract Award Q1-Q2 2024
- Delivery into Business As Usual for RIIO-T3 (2026 onwards)

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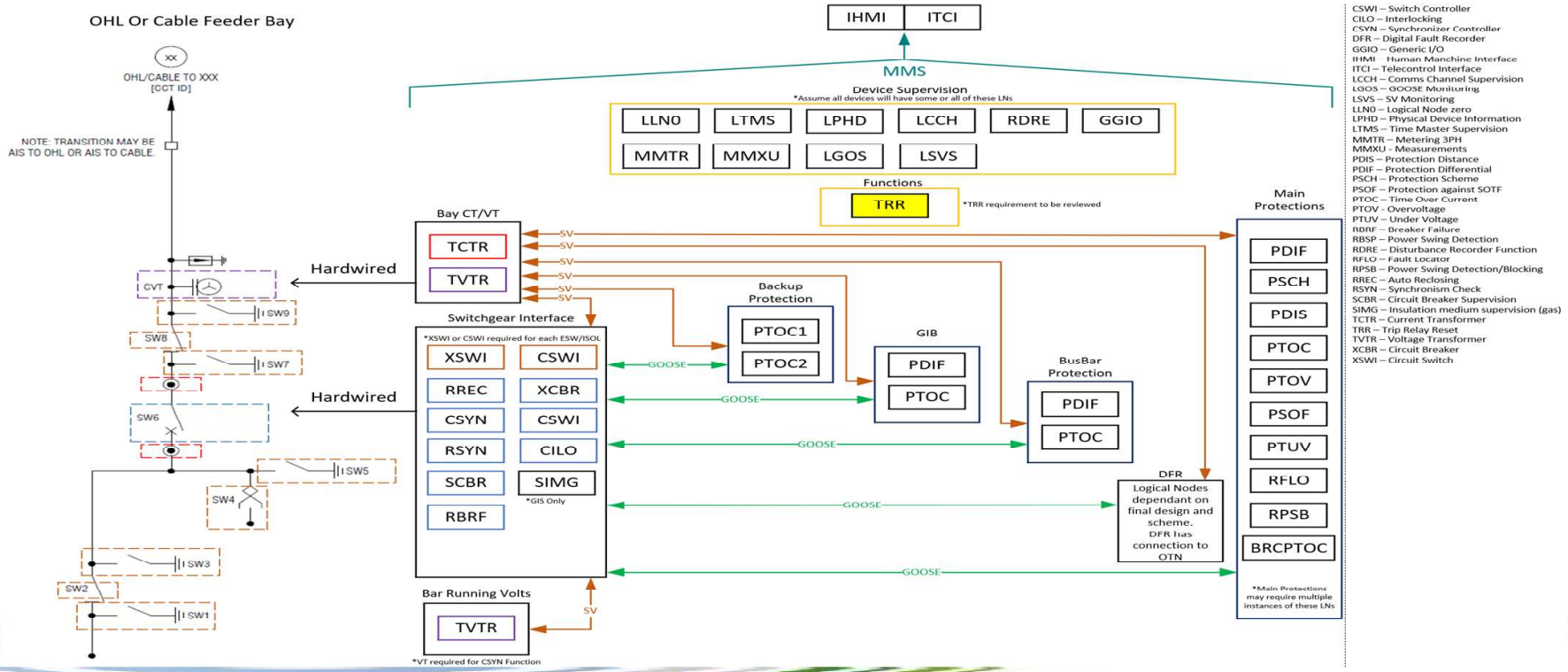
Digital Substations

Research Work

- Functional Design Specification (FDS) created to build ideal substation for the network. Making this FDS as benchmark for technology assessments
- Involves two major tasks:
  - Market readiness
    - Devices availability in the market to meet FDS criteria
    - Ensure multi-vendor solutions exists for each application
    - Limitations of the components compared against FDS
    - Pushing limits on the technology with the vendors
  - Solutions for known traditional challenges. This includes:
    - Delayed Auto Reclose (DAR) and its auxiliary functions associated with overall application
    - Voltage Selection Scheme (VSS) which is extensively deployed in the UK
    - Busbar Protection (BBP) fully centralised as opposed to distributed and its challenges
    - Trip Circuit Supervision (TCS) application

Digital Substations

Logical Node Definition



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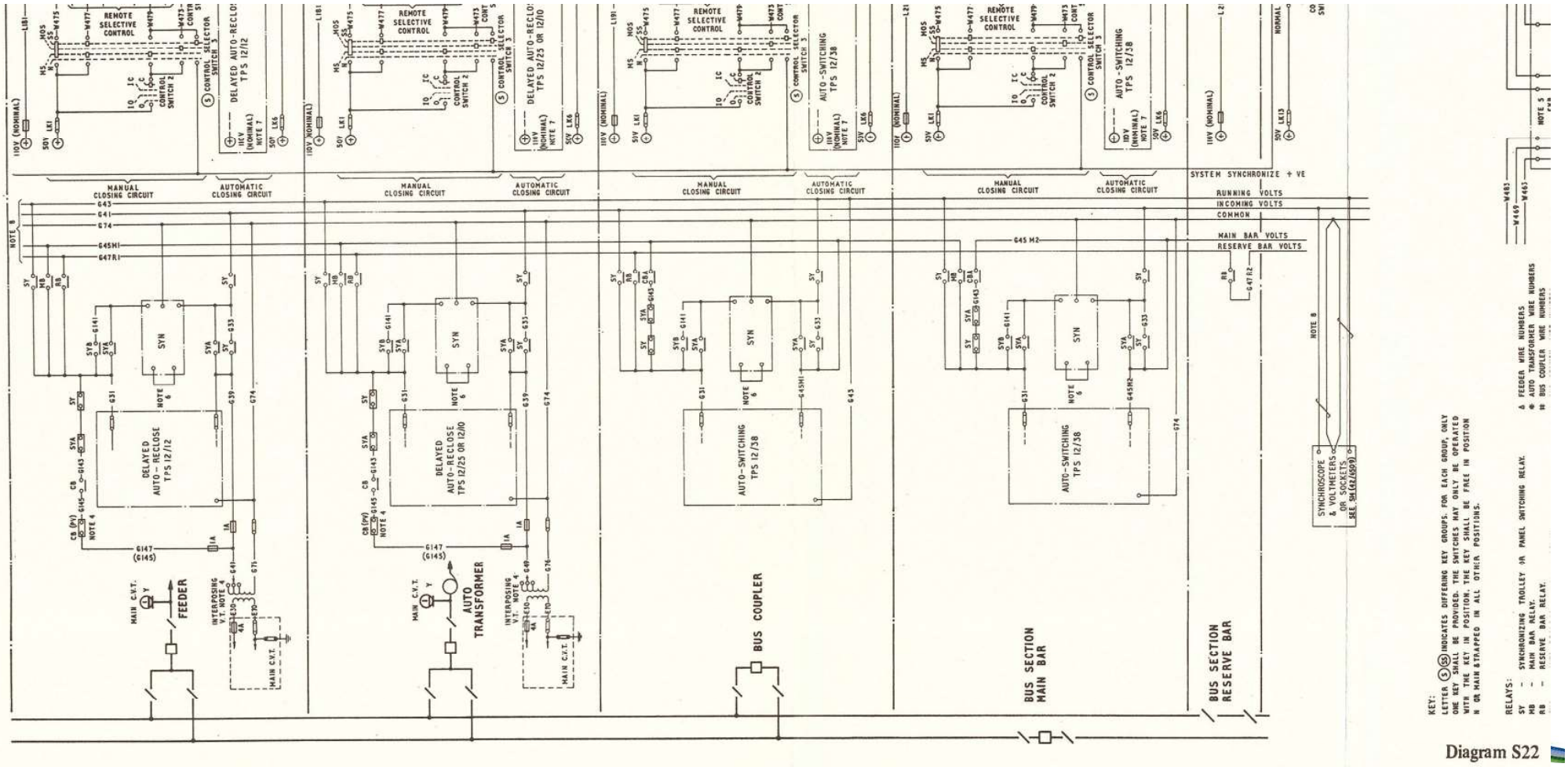
Voltage Selection Scheme (VSS)

Background

- Specified this requirement in our FDS that Busbar VT shall not be installed
- Engagements with IED manufacturers for viable solutions
- Detailed review of the proposed solutions vs feasibility of implementation, future expansion
- Selecting agreed solution(s)



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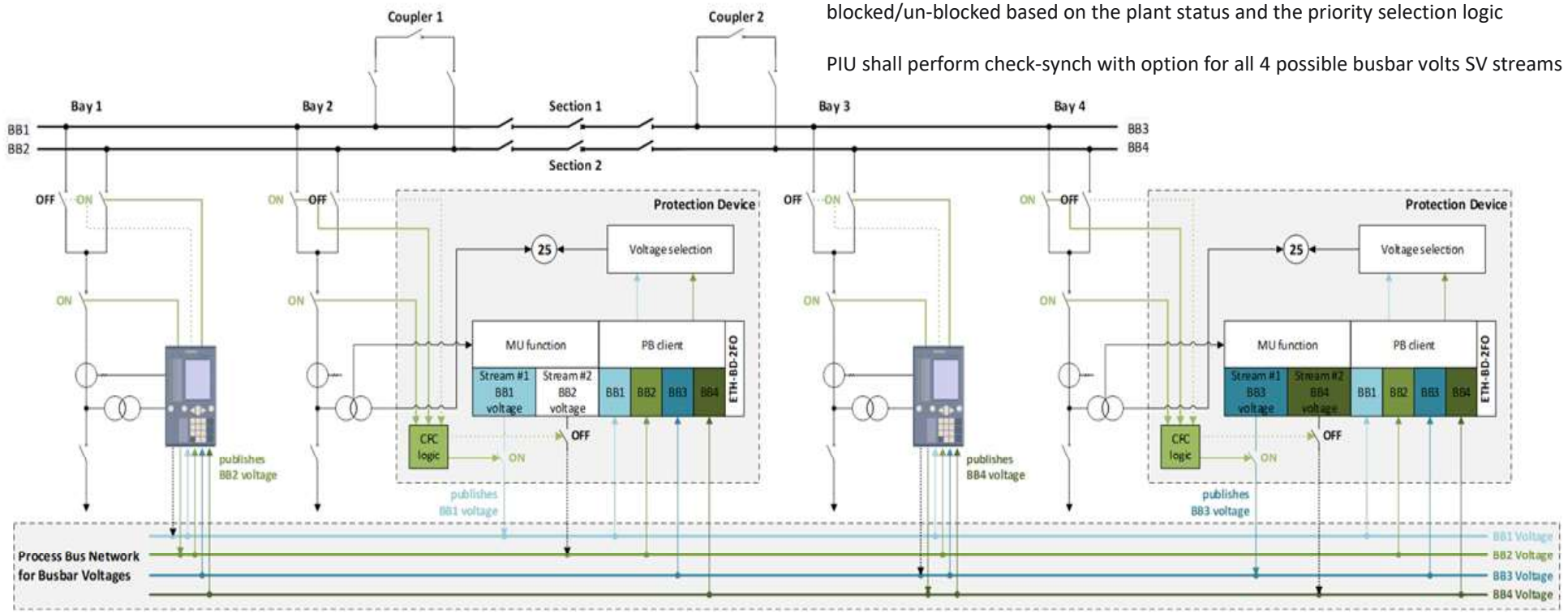
Option -1 (IED-A Solution)

Key Features:-

Each MU to publish SV of Main and Reserve busbar volts streams. The SV are blocked/un-blocked based on the plant status and the priority selection logic

PIU shall perform check-synch with option for all 4 possible busbar volts SV streams



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Option -1A (with central VSS)

Key Features

- Same as Option 1 with Logic of Busbar volts publishing within the Central VSS
- Central VSS to subscribes to all the bays and publish Busbar Volts for each zone
- Decision of priority bay selection within this Central VSS
- The central VSS holds the dynamic configuration of the substation
- Approx 20 to 27 steams can be available. With VSS on either side of MBS a total of 58 bays possible

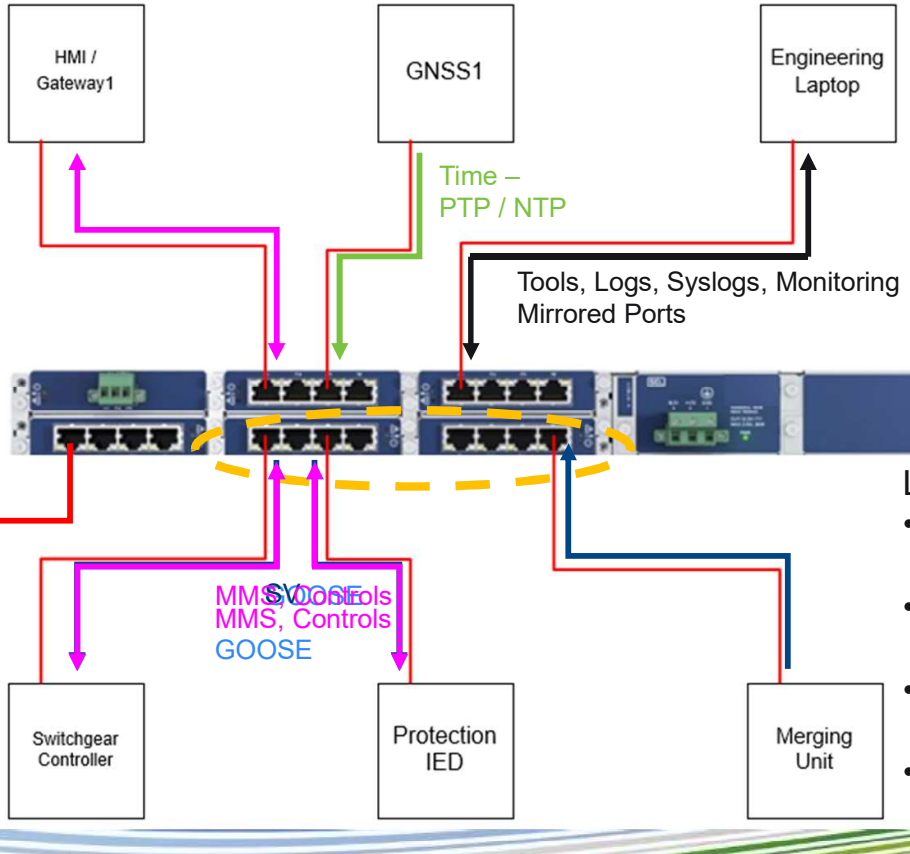
Advantages

- Significant reduction of logic
- Only the Central VSS device needs updating for addition of bay(s) in the substation

Disadvantages

- Outages required for testing during expanding bay(s)
- Another device required for redundancy point of view. From the same vendor

SDN Flow Controller Configuration



SEL_SHAPE	Protocol
Name	ICMP
Purpose	ping

```
<GSE cbName="gcb_f1" ldInst="Application">
<SMV cbName="MSVCB01" ldInst="Mod2_MU1">
  <Private source="1686743781399" type="HELINKS_TAG"/>
  <Address>
    <P type="MAC-Address">01-0C-CD-04-01-FF</P>
    <P type="APPID">4000</P>
    <P type="VLAN-PRIORITY">4</P>
    <P type="VLAN-ID">000</P>
</GSEControl>
```

EthDst	
EthSrc	
EthType	IPv4
VlanVid	
VlanPcp	
IpProto	ICMP
Ipv4Src	
Ipv4Dst	
TcpSrc	
TcpDst	102

Logical Process Bus

- Process bus traffic is limited to the ports and flows configured
- IED can use same Ethernet ports for multiple protocols
- Removes the requirement for additional Process Bus architecture, configuration and management
- Reduced traffic Bandwidth

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Option -2 (SDN Solution – with central VSS)

Key Features

- The central VSS holds the dynamic configuration of the substation
- Central VSS to control and allows dynamic connection between the publishing MU and specific Subscribing PIU for the Busbar Volts.
- Decision of priority bay selection within this Central VSS

Advantages

- No logic within MU or PIU
- Only the Central VSS device needs updating for addition of bay(s) in the substation
- No limit of bays for the substation
- No impact on the network bandwidth as the SVs are blocked at the port and enabled only on demand

Disadvantages

- Vendor specific solution
- Switching of SV using non-GOOSE solution.
- Another vendor design development requires additional costs/time and impacts to project

Redundancy

- Optimising the available devices (MU and PIU) in the event of failure
- Explore the option of using SDN with switch-on logic with RTAC (Real Time Automation Controller)
- Known technique for switching of paths
- RTAC to store and reacts to dynamic configuration change of the substation
- Failsafe option

Advantages

- Only RTAC needs updating for addition of bay(s) in the substation
- Reaction from single device

Disadvantages

- Single vendor solution
- Still to prove logic both for switching and reverting to normal
- What if……

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