

Electricity Transmission

Energy Innovation Summit, November 2025

DELIVER: Digital-Twin Enabled Innovation for Network Restoration

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NGET

nationalgrid



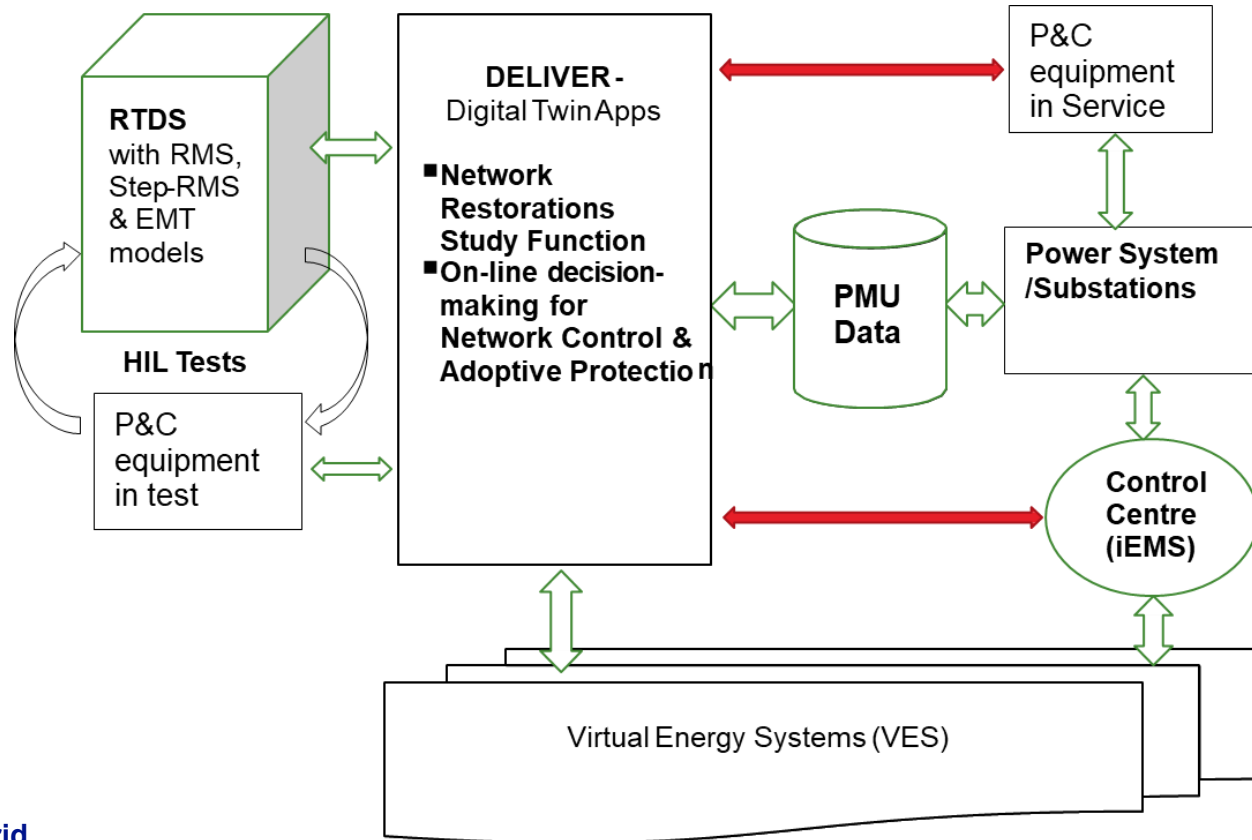
Background



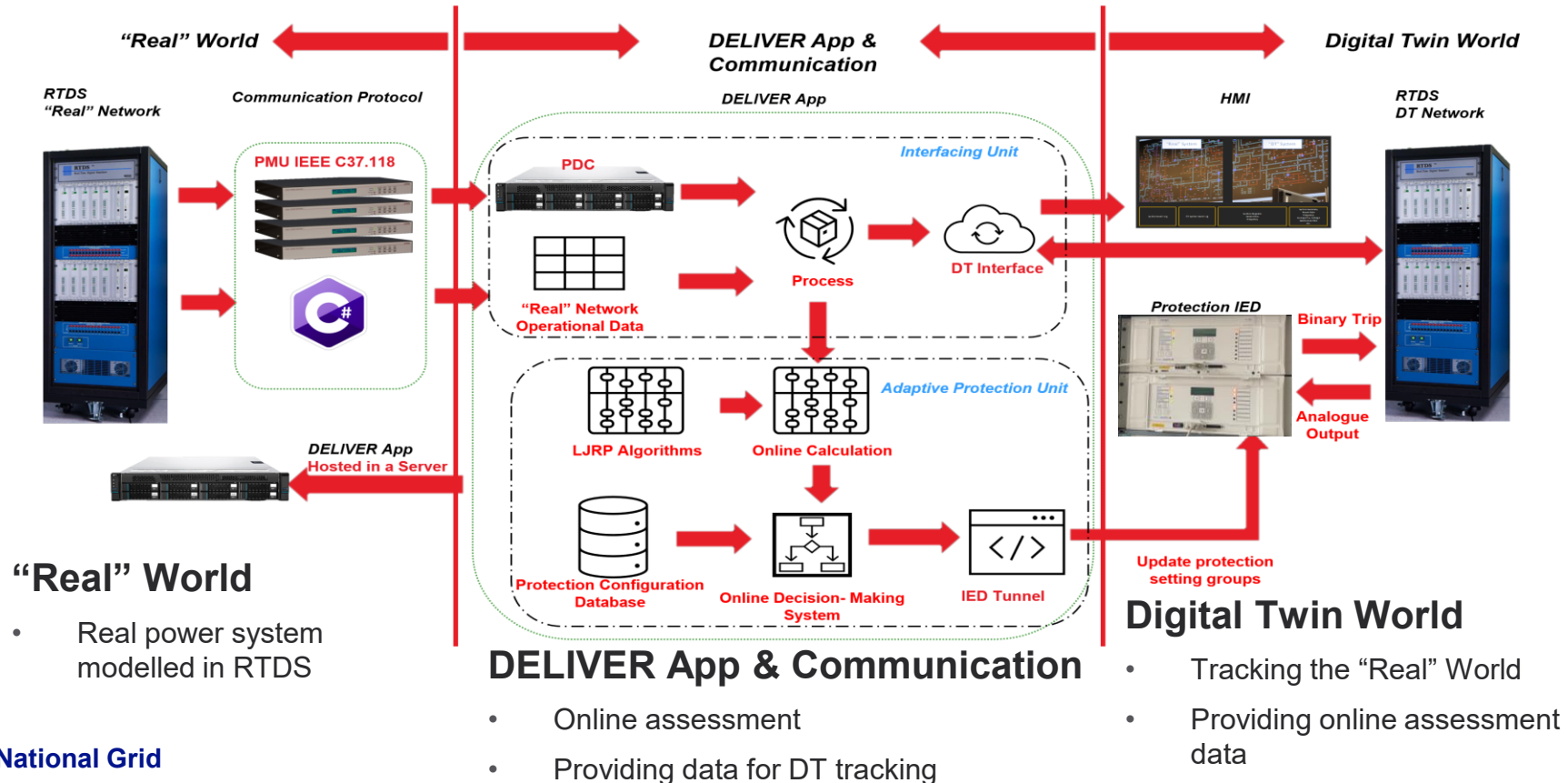
Aim and Objectives

- ❑ The **aim of DELIVER project** is to investigate the feasibility of using Digital Twin (DT) methodology for network restoration and adaptive protection
- ❑ The **objectives of DELIVER project** are:
 - To **develop a Digital-Twin System** for network restoration and adaptive protection
 - To **develop a study tool** to support the implementation of the newly published electricity system restoration standards (ESR)
 - To **perform on-line analysis** of the local system restoration plans
 - To **provide on-line decision-making support** for network restoration
 - To **provide adaptive protection** e.g. on-line change setting groups or block P&C equipment

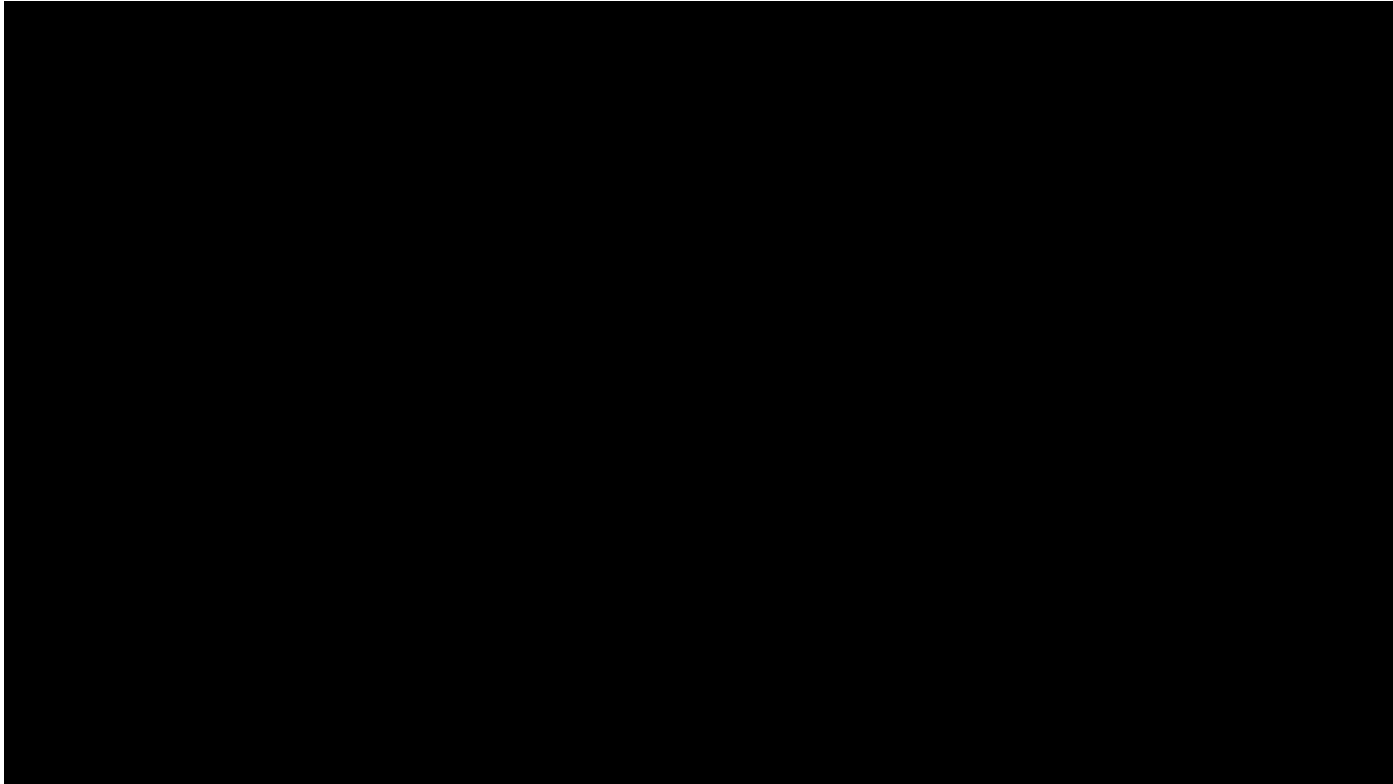
Conceptual Architecture Design of DELIVER Project



Laboratory Hardware Architecture Design for DT System



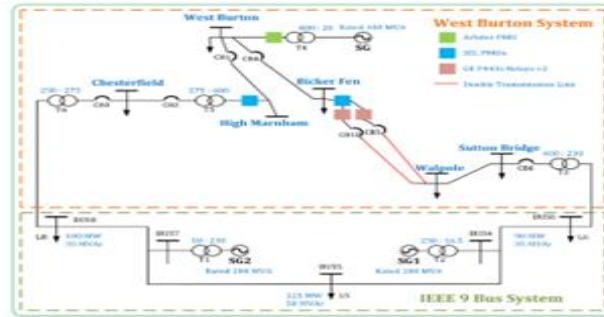
DELIVER Functions



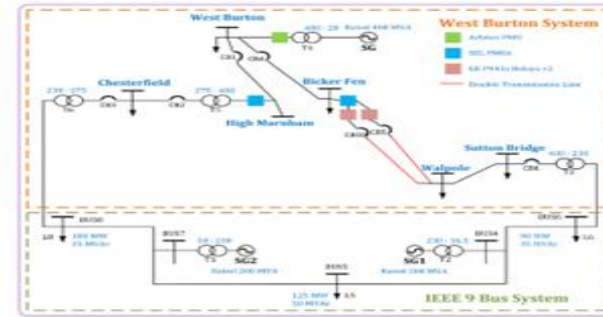
DELIVER App & Online User Interface

System Topology Comparison

Real System

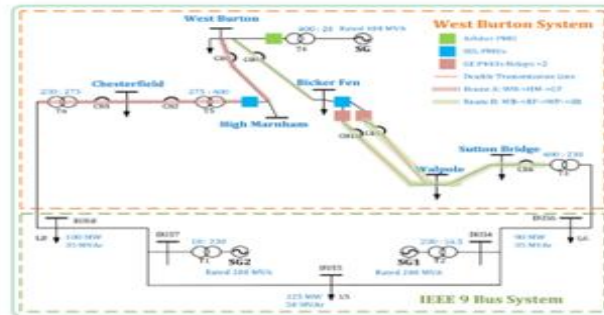


Digital Twin System

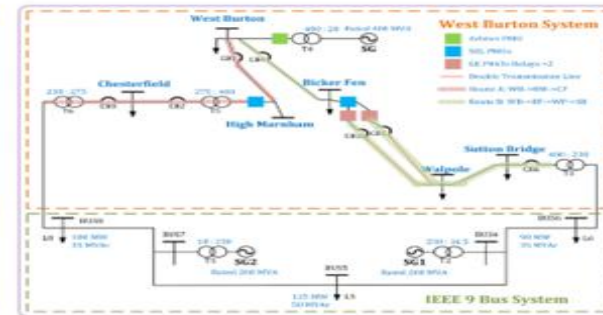


Restoration Routes

Route A



Route B



DELIVER App & Online User Interface

DELIVER App: Digital-Twin Enabled Innovation for Network Restoration [Dashboard](#)

Digital Twin System Operation Status Overview

Simulator Running Status	Simulator Connection Status	Operation Lock Status
Stopped	Connected	Not Acquired
Acquire Lock	Release Lock	Force Release Lock

Restoration Analysis Check List :

- ☐ Total Restoration time
- ☐ Active & Reactive Power
- ☐ System Bus Voltage
- ☐ Temporary Over Voltage (TOV) Check
- ☐ Infrequent Rapid Voltage Change (RVC) Check
- ☐ Frequency Variation Check
- ☐ Circuit Breaker Transient Recovery Voltage Check
- ☐ Protection Assessment

Restoration Check List

Route A	Run Check Restoration List	Route B	Run Check Restoration List
Time to recover to targeted state. Target Time: 600 seconds Change Success		Time to recover to targeted state. Target Time: 600 seconds Change Success	
Restored energy within given time frame. Target P: 80 MW Change Success		Restored energy within given time frame. Target P: 80 MW Change Success	
Voltage variation within limits? Rated: 400 kV Upper Offset: 10 % Success Lower Offset: 10 % Change		Voltage variation within limits? Rated: 400 kV Upper Offset: 10 % Success Lower Offset: 10 % Change	
TOV within limits? Success		TOV within limits? Success	
RVC within limits? Success		RVC within limits? Success	
Frequency variation within limits? Rated: 50 Hz Upper Offset: 0.1 Hz Success Lower Offset: 0.1 Hz Change		Frequency variation within limits? Rated: 50 Hz Upper Offset: 0.1 Hz Success Lower Offset: 0.1 Hz Change	
CB TRV compliance? Success		CB TRV compliance? Success	
Protection maloperation? Success		Protection maloperation? Success	
Protection correctly detects faults? Success		Protection correctly detects faults? Success	

DELIVER App & Online User Interface

Restoration Check List Analysis

[Reset All Switches](#) [Run Route A \(Restoration assessment\)](#) [Run Route B \(Restoration assessment\)](#) [Run Route C](#)

Route A Analysis Grid

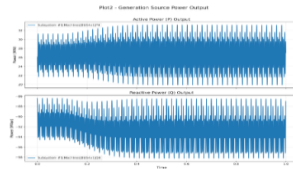
Grid Last Updated: 23:03:07

Time to recover to targeted state.

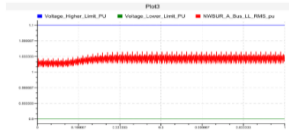
514.1 s

(System Stable)

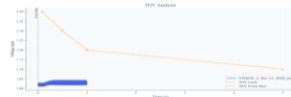
Restored energy within given time frame.



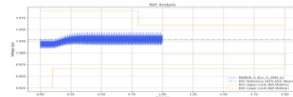
Voltage variation within limits?



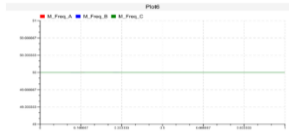
TOV within limits?



RVC within limits?



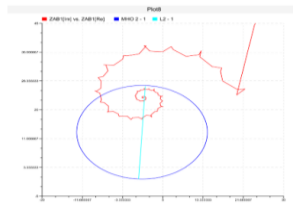
Frequency variation within limits?



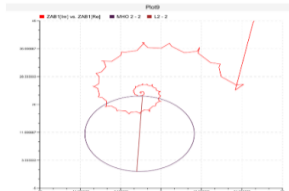
CB TRV compliance?



Double-line Zone 3 fault system impedance with double-line Zone 2 setting



Double-line Zone 3 fault system impedance with single-line Zone 2 setting



Real-time Monitoring

Real-time System Metrics

Connected to API [Use Mock Data](#) Last updated: 23:22:50 ☒ Auto Control (ON)

Active Power

26.65 MW

Reactive Power

-91.31 MVar

Voltage

407.5 kV

Frequency

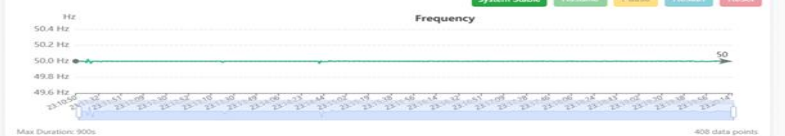
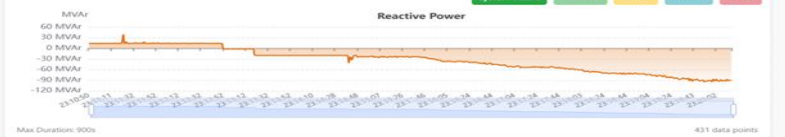
50.000 Hz

Stable Indicator

Stable

Real-time Trend Charts

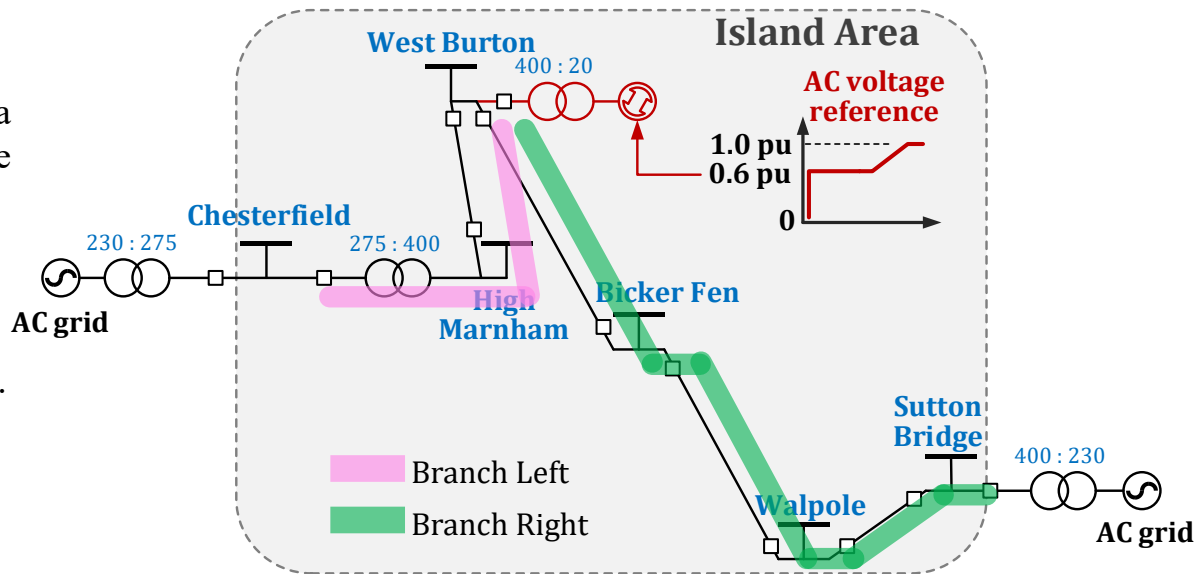
Max Duration: 15 min Continue After Stable: 1 min [Start All](#) [Pause All](#) [Restart All](#) [Reset All](#)



Network Restoration: Black Start via SGs

Inrush Current Mitigation: Low-Voltage Soft Energization

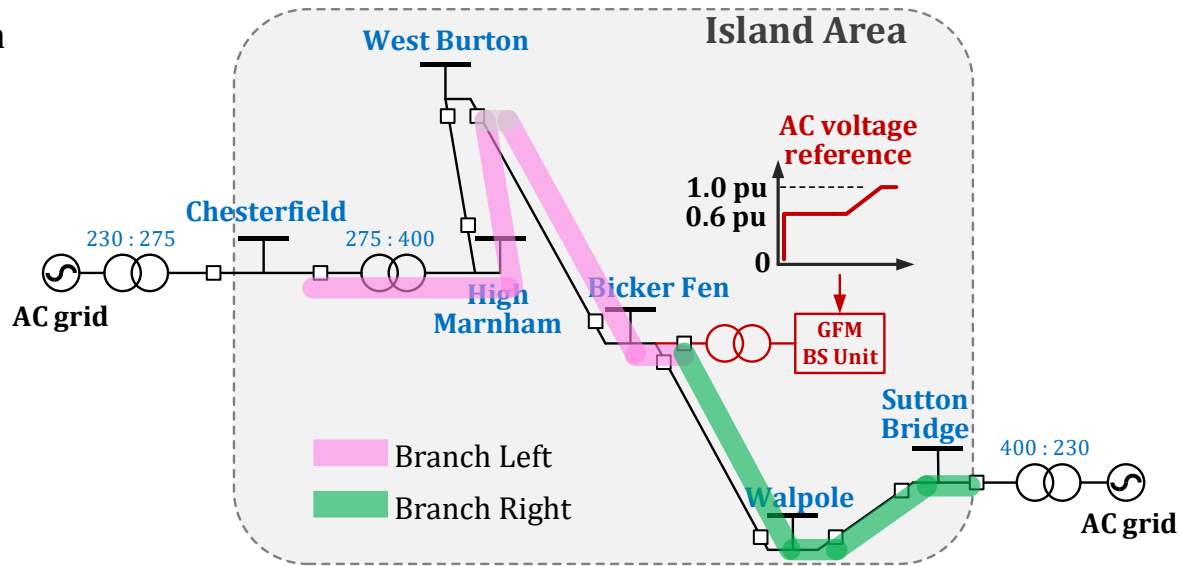
- ✓ Gradually energize the island area at voltage of 0.6 pu – close the circuit breakers one by one.
- ✓ Voltage ramps up to 1.0 pu.
- ✓ Resynchronized with the AC grid.



Black Start via GFM Technologies

Low-Voltage Soft Energization

- ✓ Gradually energize the island area at voltage of 0.6 pu – close the circuit breakers one by one
- ✓ Voltage ramps up to 1.0 pu
- ✓ Resynchronized with the AC grid

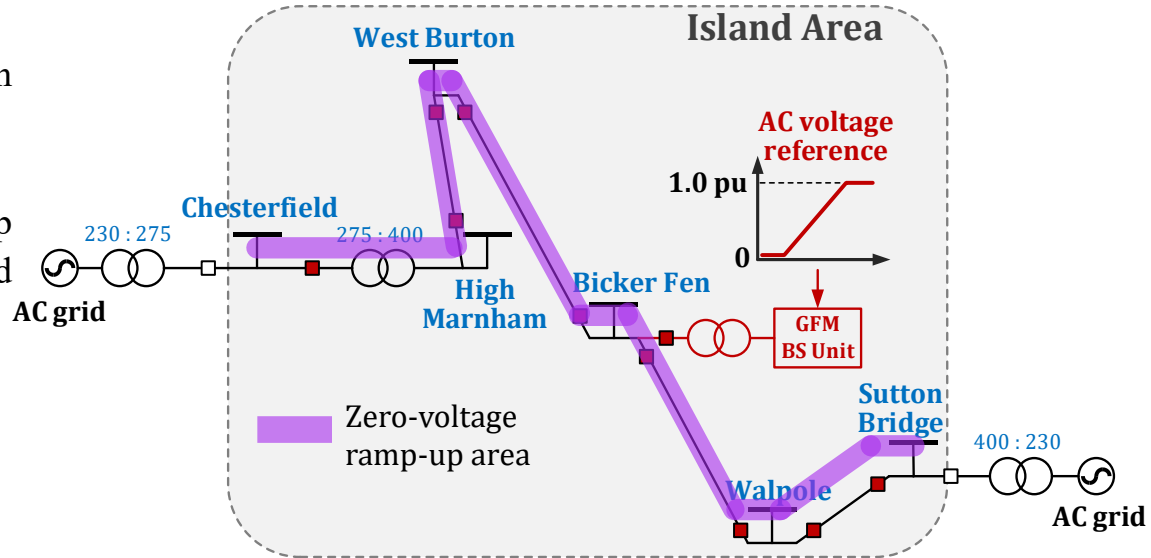


Two Routes for Each GFM Technology (Left & Right)

Black Start via GFM Technologies

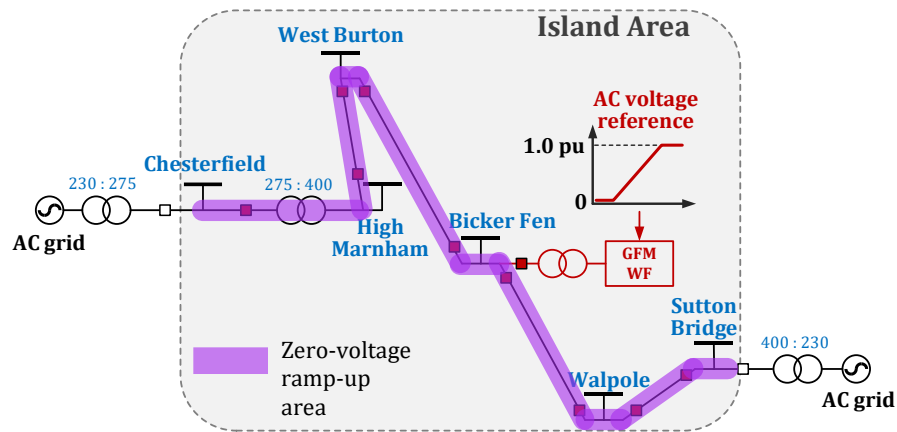
Zero-Voltage Ramp-up Strategy

- ✓ Close all the circuit breakers within the island system at the beginning
- ✓ The GFM black start unit ramps up the voltage of the entire island network from 0 V
- ✓ Resynchronized with the AC grid

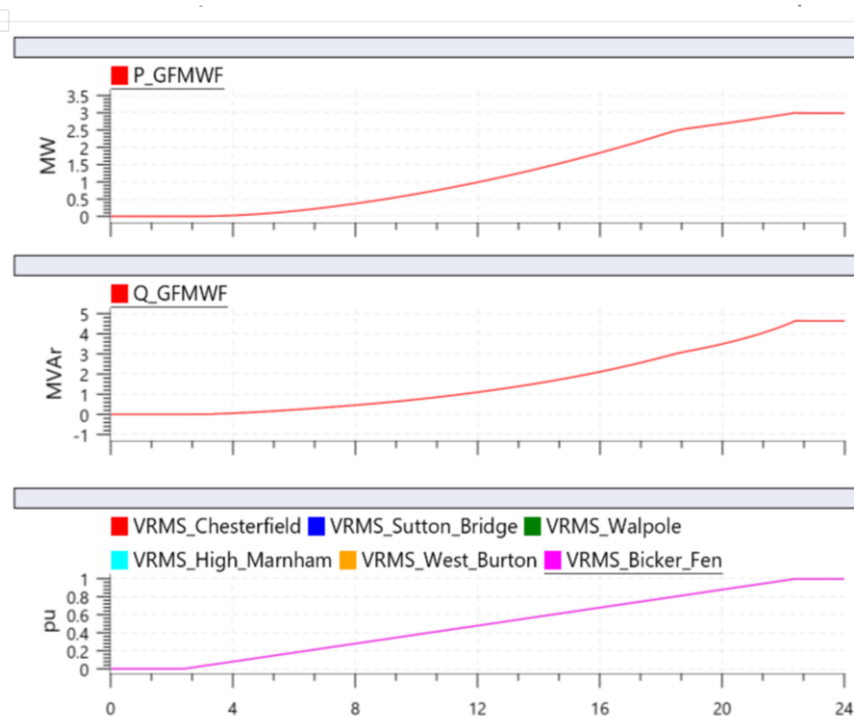


Black Start via GFM Technologies

Zero-Voltage Ramp-up Strategy - GFM WF

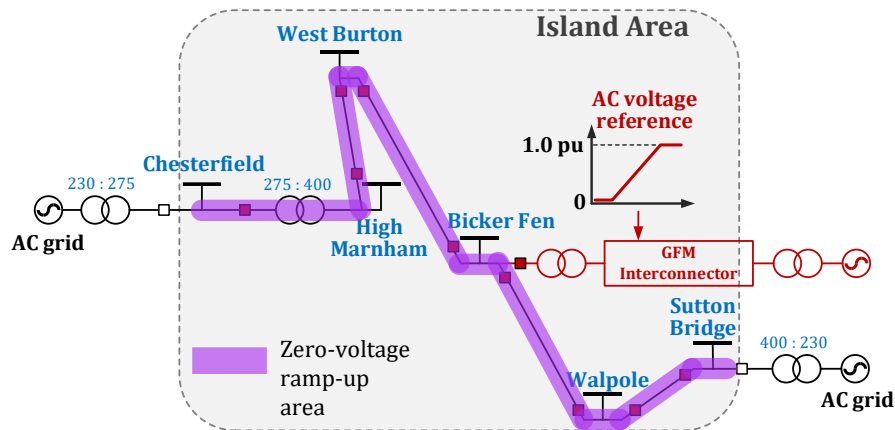


A fast and stable black start process of the entire power island within short time.

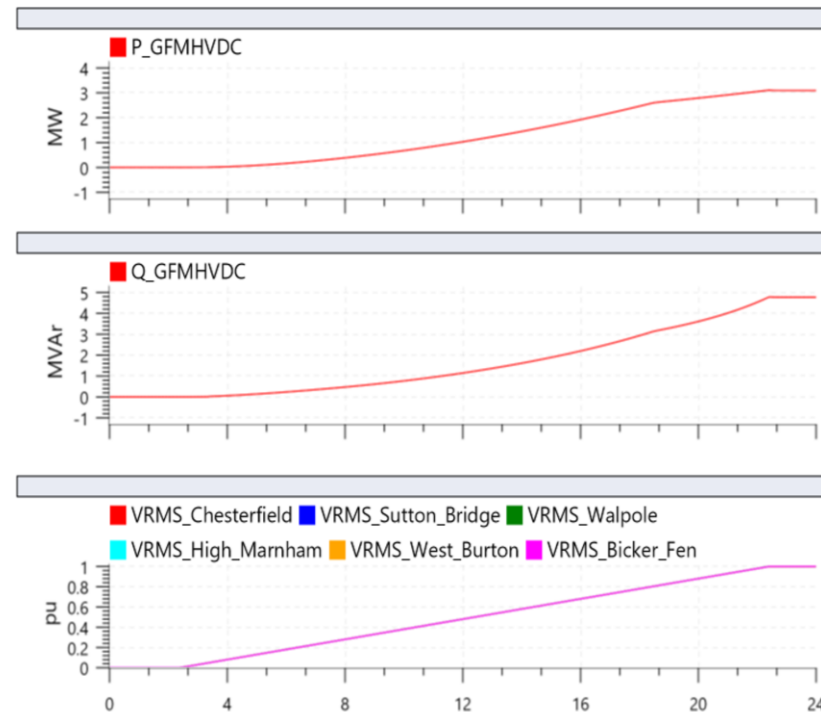


Black Start via GFM Technologies

Zero-Voltage Ramp-up Strategy - GFM HVDC Interconnector



A fast and stable black start process of the entire power island within short time.



Summary

- ❑ The project has successfully achieved the set out key objectives.
- ❑ Dissemination workshop with lab demo was held in September 2025 with industry stakeholders from SSEN, SPEN, NESO and NGET.
- ❑ **A demonstrator of the DT system** was showcased in the lab in Birmingham university.
- ❑ The **DELIVER App** was developed successfully with **study toolbox** to support network restoration planning and decision making.
- ❑ The **benefits of the DT system** for network restoration include:
 - ✓ **Supporting** the new electricity system **restoration standards** (ESR)
 - ✓ **Performing on-line analysis** of the system restoration plans
 - ✓ **Supporting on-line decision-making**
 - ✓ **Providing adaptive protection**
 - ✓ **Enhance the efficiency and reliability of the restoration**

Electricity
Transmission

Q&A

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