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System Operation and Control

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Development and validation of new organisational models and systems for DER led restoration

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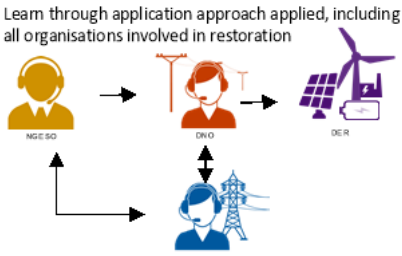
Motivation

- As the GB electricity market becomes more decentralized, decarbonized and digitalized so the approach to Power System Restoration must change
- Work undertaken as part of the Distributed ReStart project developed organizational models, telecommunications requirements and control systems to enable resilient control of distributed energy resources under a system restoration scenario.

Method and Approach

- Extensive consultation with all organizations involved in GB restoration was used to baseline and identify risks
- Parallel development of technical requirements including telecommunication and cyber security capabilities was undertaken.
- Real world tests were conducted through desktop exercises, live network trials and system prototype real time digital simulation with hardware in the loop tests



Objects of investigation

- Create an end- to- end specification for the power systems, organisational, telecommunications, network code and procurement requirements to facilitate restoration from distributed assets
- Develop an organisational structure to facilitate the power systems findings and maximise the restoration speed whilst at minimum total cost to the end consumer
- Develop a functional specification for the control systems required to support the power systems and organisational capability gaps
- Define the functional telecommunications requirements for this process
- Demonstrate the effectiveness of the organisational designs through application using desktop exercises
- Demonstrate the effectiveness of the control system through real time digital simulation on a prototype

Experimental setup & test results

- A custom electricity simulator was developed enabling remote access to a common platform for DNOs, ESO, TO and DER. Feedback was collected to identify improvements and blockers in the process design
- 4 vendors were selected to develop a control system specification, the outputs of these were collated to create a functional specification from which a single vendor then developed the prototype for HiL testing

Discussion

- Organisational change will be needed to facilitate distributed restoration
- Local voltage and frequency management by distribution system operators is a very significant change but was accepted by all stakeholders
- No blockers were identified but multiple improvements were captured and incorporated into the final design.
- An online, interactive platform emulating control systems led to very high-quality improvements being identified and confidence in the processes developed
- Learnings from this development exercise can be applied to in-service training
- Engaging multiple vendors for an initial control system functional specification promoted competition, allowed for exploration of various conceptual design principles and led to overall improvements in the prototype build

Conclusion

- A working model for distribution level restoration has been developed and is being procured in GB as part of ongoing regional tenders
- Significant organizational, control system and power systems changes are needed to facilitate restoration from DER
- Changes identified and implemented from desktop exercises enabled significant refinement and development of the final organizational design
- Whilst these changes incur costs, the benefits of enhanced competition, decarbonisation and future proofing of an essential system capability leads to a net consumer benefit of between £86m and £144m
- Power engineering, control system and organizational challenges continue to exist in the models developed but ongoing training, assurance testing and infrastructure build will continuously refine the specifications

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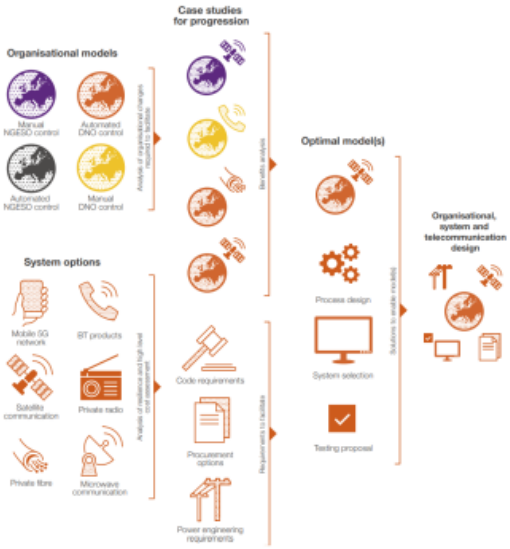
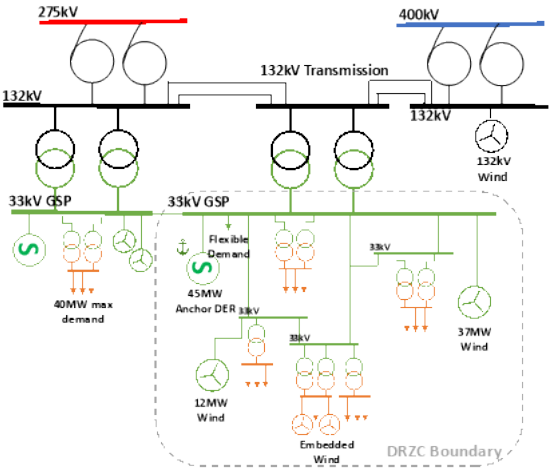
Viability assessment



Restoration Zone

- The boundaries of responsibility for control system design and organisations are linked to a distribution restoration zone
- A distribution restoration zone is a combination of network, energy resources and demand which act as an effective restoration provider



Roles and responsibilities

A central organisational model was developed:

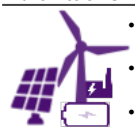
- ESO continue to coordinate national restoration including instructing the start of plans
- DNOs lead locally and use a control system for management of real time frequency, voltage and generator dispatch

- Declare Black Start
- National strategy
- Regional strategy
- Instruct restoration zone start
- Instruct transmission restoration route
- Instruct power island growth

System operator

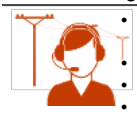
- Transmission network switching actions
- Data provision to DNO
- Co-develop transmission level strategy

Transmission Owner



- Multiple individual providers deliver different services to the restoration zone
- Anchor DER provides the initial voltage and frequency source
- Top-up service providers support power island growth

Distributed Energy Resource

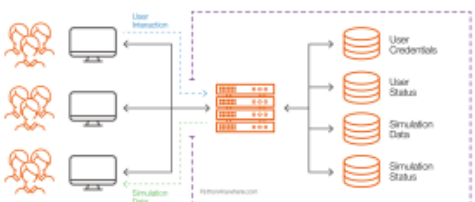


- Declare and instruct restoration to service providers
- Develop local restoration strategy
- Distribution network switching actions
- Local voltage and frequency management

Distribution Network Operator

Desktop Exercises

- A full end to end process based upon the Chapelcross restoration zone (left) and the organisational model (above) was conducted. A process map was developed
- This exercise included control engineers from all key organisations involved in the technical procedure and simulated an end-to-end restoration on an online platform



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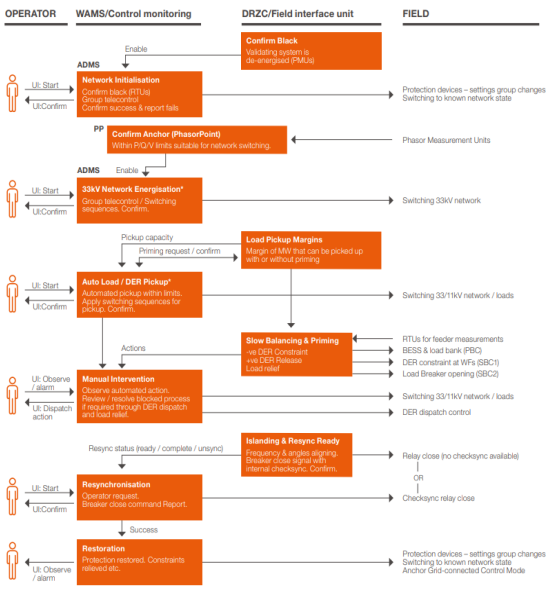
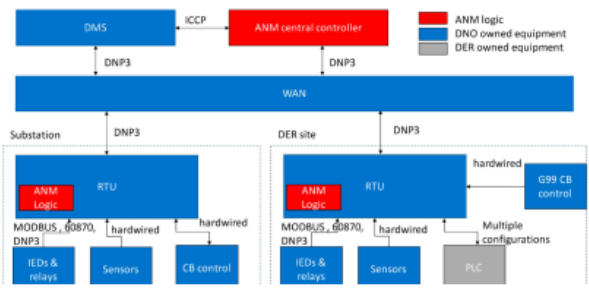
Restoration Zone Control System

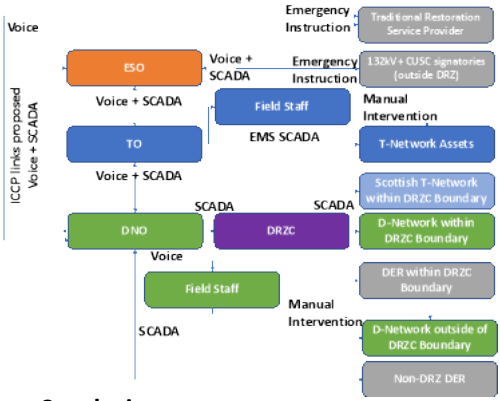
- Four different vendors were engaged to develop front end engineering designs for a control system
- A single vendor was then selected to build a prototype. The key functions and interactions with this selected design are detailed below
- Fast balancing functions maintain network stability through sub second control enhancing block load pickup capability of energy resources
- Slow balancing maintains appropriate energy distribution across the restoration process



- The communications and control architecture that facilitates these processes is summarized in the graphic below



Telecommunications interface map



Conclusions

A working model for distribution level restoration has been developed and is undergoing procurement in GB

- Cost benefit analysis has demonstrated expected consumer benefit of between £86m and £144m
- However, this model increases the complexity of restoration and leads to the following significant change requirements:

- Inter control centre protocol required for visibility between the DNOs and System Operator.
- Enhanced training requirements

System operator

- Phasor Measurement Units and data exchange with DNO to facilitate synchronisation
- Additional network synchronising points

Transmission Owner

- New power resilience and communications specification
- Technical changes to deliver contracted service
- Robust training and minimum staffing requirements

Distributed Energy Resource

- Restoration control system implementation
- New power resilience and communications requirements
- Significantly enhanced training requirements
- Potential additional staff requirements

Distribution Network Operator