National Grid ESO & Western Power Distribution

SYSTEM HILP EVENT DEMAND DISCONNECTION (SHEDD)

Project Summary Report for E3C Engagement
(As part of the project workshop: Deliverable 3.2)

70067939
JUNE 2021

PUBLIC

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TYPE OF DOCUMENT PUBLIC

PROJECT NO. 70067939

OUR REF. NO. 70067939

DATE: JUNE 2021

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QUALITY CONTROL

Issue/revision	First issue	Version 2
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Project number	70067939	70067939

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1 INTRODUCTION

1.1 PROJECT OVERVIEW

WSP[1], Cornwall Insight[2] and Complete Strategy[3] are undertaking a Network Innovation Allowance (NIA) funded innovation project – System HILP Event Demand Disconnection (SHEDD) – on behalf of National Grid Electricity System Operator[4] (NG ESO) and Western Power Distribution[5] (WPD).

The project investigates alternative LFDD design options with the aim of evaluating the potential technical, economic, and social performance improvement through implementation of these alternative LFDD options within short (≤ 5 years) and medium-long (> 5 years) terms.

1.2 BACKGROUND

Following the 9th August 2019 blackout event, the performance of the Low Frequency Demand Disconnection (LFDD) scheme has been given significant attention. The Energy Emergencies Executive Committee (E3C) final report on the 9th August 2019 GB blackout event has stated the clear need for further improvements in the performance of existing LFDD schemes [1].

A key challenge is the underestimation of the demand disconnected by the LFDD protection relays during the event in addition to other technical factors which have been explored within previous studies of the scheme [2] [3]. Furthermore, there is also a limited understanding of the economic and social impact to network customers from operation of current schemes and its associated disruption.

In response to this challenge, the SHEDD NIA innovation project funded by NG ESO and WPD reviews the GB LFDD schemes to investigate the potential benefits of introducing a new design to the LFDD scheme which can better protect the network from sudden severe deviations in the system frequency, whilst minimising the impact to network customers. The project provides recommendations and specifications of how these alternative solutions can improve the performance of the LFDD schemes in the future as electricity networks continue to transition towards Net Zero.

1.3 PURPOSE OF THIS WORKSHOP

The key objective of the workshop is to gain feedback on the final shortlisted solutions from pervious deliverables and generate insights on the technical, regulatory, policy, operational, and commercial barriers to overcome before deployment as Business as Usual.

It is intended that this report summarise the project and disseminate the current progress undertaken towards understanding these barriers to better drive the discussion section of the workshop.

[1] https://www.wsp.com/en-GB
[2] https://www.cornwall-insight.com/
[3] https://complete-strategy.com/
[4] https://www.nationalgrideso.com/
[5] https://www.westernpower.co.uk/

2 OVERVIEW OF SHORTLISTED LFDD OPTIONS

The following provides a summary of the shortlisted alternative LFDD scheme options proposed in Work Package WP3 (D3.1 [4]) and later re-classified in Work Package WP4 (D4.2 [5]) based on their technical, commercial, societal, and environmental performance.

2.1 SHORT-TERM DESIGN OPTIONS (≤ 5 YEARS)

The short-term alternative solutions for the LFDD scheme are defined as those which represent least disruption to current ways of working, allowing the solutions to be implemented by GB DNOs within five years and with relatively limited additional cost or resource requirements.

2.1.1 OPTIMISATION OF LFDD RELAY SETTINGS

"Optimisation of LFDD Relay Settings" scored the best in Deliverable 3.1 and 4.2. This solution focuses on the optimisation of key parameters and settings associated with the LFDD schemes to maximise its technical performance. These parameters include the percentage of loads connected to each under-frequency stage of the LFDD scheme, under-frequency thresholds associated with each LFDD stage, frequency dead-bands, and the relay time delay settings.

These parameters can be re-optimised based on the dynamic characteristics and strength of each protected region, the associated consumer impact, and Value of Lost Load (VoLL) to improve the technical and economic performance of the targeted LFDD scheme.

2.1.2 DISABLING LFDD RELAYS DURING POWER EXPORT

This alternative solution requires the LFDD relay to be deactivated temporarily when the network connected downstream of the relay-protected area is exporting power from Distributed Generation (DG) sources. This prevents large quantities of DG from being disconnected from the network which would worsen the frequency drop associated with any HILP event. The relay will then be programmed to return to a default position (normal) when the protected network area returns to be a net importer.

2.2 MEDIUM-TERM LFDD DESIGN OPTIONS (> 5 YEARS)

The medium-term LFDD alternative solutions were defined as those which are relatively more complex and sophisticated than the short-term options, with a lower Technology Readiness Level (TRL) or increased barriers to implementation.

2.2.1 RELOCATION OF LFDD RELAYS TO LOWER VOLTAGES WITH DISABLING DURING POWER EXPORT FUNCTIONALITY

An output of D4.2 was the reclassification and shortlisting of short- and medium-term solutions. D4.2 also identified the potential to improve the performance of the "*Relocation of LFDD Relays to Lower Voltages*" by combining it with the *"Disabling during power export functionality"*.

This alternative LFDD solution combines the two topologies, moving the LFDD relays visibility from the 33kV network to lower voltages (11kV). This results in the redirection of the LFDD trip singles to the circuit breaker of primary transformers or/and outgoing feeders' instead of tripping the entire substation. The performance of the *"Relocation to Lower Voltages"* can then be improved by temporarily deactivating the LFDD relays when the network connected downstream of the relays is exporting power from DG sources.

3 CONSUMER IMPACT

Through Work Package 2 Cornwall Insight have been assessing potential options to account for consumer impact within the LFDD scheme. The intention is to understand whether it is appropriate and possible to change how consumers are considered in the decisions about where LFDD relays should be placed.

In Deliverable 2.1 we noted there are a number of ways that consumer impact could be reflected. These were broadly categorised into two groups:

- **Quantitative approaches** – where Value of Lost Load (VoLL) data is used to determine the location and ordering of LFDD relays. VoLL is an administratively determined value to estimate the value that consumers may place on continued security of supply
- **Qualitative options (non-VoLL based options)** – where other approaches could be taken to differentiate between different customer types, including whether it would be possible or appropriate to differentiate customers that are defined as critical or essential, domestic or vulnerable

In Deliverable 2.2 we assessed these options on both a standalone basis, and against the technical LFDD options. We noted that:

1. In practice, DNOs are already accounting for customers in their placement of LFDD relays;
2. There is ongoing thinking by Government to progress two actions from the E3C report related to customers in the LFDD; and,
3. Recognising the nature of the LFDD scheme and the available technologies, quantitative options such as reflecting VoLL in the placement of LFDD relays would face a number of issues and be subject to a number of caveats and assumptions. For these reasons we do not believe VoLL should be used as an initial decision metric, but that it could be used in a 'tie-breaker' situation.

In Deliverable 2.3 we are setting out a methodology that could be used to assign substations with a value based on VoLL. This is based on the following assumptions:

- It would be appropriate to differentiate between different customer types in this way
- DNOs would welcome an additional decision-making tool based on VoLL to support their decisions
- VoLL data is available, and that data is appropriate for use in LFDD outages

The methodology is based on available data flows to estimate demand by different customer types for different substations.

4 BARRIERS FOR IMPLEMENTATION

4.1 OVERVIEW

This section focuses on the assessment methodology used to understand the implementation barriers of each shortlisted LFDD alternative design. It discusses the approach taken and the individual assessment of each of the shortlisted alternative solutions.

4.2 ASSESSMENT APPROACH

A systematic framework has been created for the assessment of potential barriers for implementation of shortlisted LFDD solutions and identify solutions to overcome them for successful deployment.

The framework focuses on identifying internal and external changes required for various parties in order to facilitate implementation. Specifically, the assessment is guided by the principles summarised in Table 4-1 which serves as the focus of this investigation.

Table 4-1 - Barriers to implementation assessment framework

Source of Barrier	Key Considerations
Technological	▪ How mature is the technology required for this solution (TRL)? ▪ Are there conflicts with existing technology that will need to be resolved? ▪ What modifications or additions are required?
Regulatory and Policy	▪ How does the solution align to relevant regulation (Network licences, the Grid Code, and Policy Arrangements)? ▪ If regulatory change is required, what is the route for progressing this? ▪ Would it require a modification, or wider consultation? Are there conflicts with existing technology that will need to be resolved?
Financial	▪ What investment is required to deliver the solution? ▪ What are the timescales for implementation? ▪ Are there financial impacts for other parties?
Commercial	▪ Does the solution interact with existing commercial arrangements? ▪ Are there any required adjustments to connection agreements?
Organisational	▪ Is the solution practical and applicable across GB DNO regions? ▪ What impact does the solution have on the existing roles of WPD, NG ESO, or any other party? ▪ Will the solution create new or change responsibilities for any of these organisations or parties? ▪ If significant change is required, are the relevant parties in a position to respond to this?
System Related	▪ Does the solution change the reliability or risk of failure? ▪ Will the solution change the complexity of the LFDD scheme?

4.3 OPTIMISATION OF LFDD RELAY SETTINGS

The barriers to overcome for the *"Optimisation of LFDD Relay Settings"* alternative solution have been identified by Table 4-2 below for each of the defined categories.

Table 4-2 - Identified implementation barriers for Optimisation of LFDD Relay Settings

Source of Barrier	Key Considerations
Technological	▪ Very high TRL reflected as no modifications are required to the existing equipment which has a strong maturity given its current deployment on WPD's distribution network. ▪ The re-design only changes the relays settings by optimising them, it can therefore be deployed on relays currently procured by WPD. ▪ Relay settings can be calculated from existing network models and power system analysis techniques and does not require new technologies to be developed for implementation.
Regulatory and Policy	▪ Solution fits in existing Grid Code framework (OC6.6 [6]) as only the settings and parameters are optimised. ▪ Policy arrangements may need to be made to identify best practice (methodologies) for characterising the protected network, quantifying customer impact, and calculating new settings.
Financial	▪ Minimal investment is required to deploy this solution. Costs are confined to the calculation of optimised relay settings and the implementation of them on the existing relay infrastructure. ▪ Operational costs may have a marginal increase from the updating of relay settings on a more regular basis. ▪ Solution could be deployed in short-term (approx. 1-2 years) given the minimal technological and financial barriers.
Organisational	▪ This alternative LFDD solution is applicable across all LFDD protection relays and sites with negligible changes to substation infrastructure. ▪ It requires minimal changes to existing roles after implementation. WPD would need to take a more active role in calculating the LFDD settings more regularly and NG ESO would have no changes to their current role. ▪ This solution does depend on the accurate calculation of the economic performance of each protected LFDD region which will need to be coordinated between NG ESO and DNOs. This is however not out with the capabilities of WPD and NG ESO to facilitate.
System Related	▪ Optimising the settings of relays is unlikely to affect the reliability of LFDD schemes given the technology's proven reliability. It will therefore have a limited effect on the risk of failure. ▪ There is minimal increase in complexity of the scheme as no new algorithms or data exchanges are needed. However, the calculation of optimised settings with accurate economic data may pose a barrier.

4.3.1 DISABLING LFDD RELAYS DURING POWER EXPORT

The barriers to overcome for the *"Disabling LFDD Relays During Power Export"* alternative solution have been identified and discussed in Table 4-3. This has been undertaken using the assessment matrix previously presented.

Table 4-3 - Identified implementation barriers for Disabling LFDD Relays During Power Export

Source of Barrier	Key Considerations
Technological	▪ High TRL as most existing LFDD digital relays integrate blocking and sophisticated monitoring with communication capabilities. Equipment produced by OEM's have the TRL required for this solution. Relays that do not have these capabilities presents a barrier to overcome. ▪ This design relies on the measurement of current and voltage to understand the power flow direction. Current LFDD schemes only measure voltage, requiring CTs for current measurement. However, directional overcurrent relays could be used to determine power flow direction using their power flow indicator, eliminating the need for CTs. ▪ New settings are needed for the deactivation of relays when reverse power flow is detected. This presents a technological barrier to overcome and could be achieved internally within the relay algorithm.
Regulatory and Policy	▪ Current Grid Code regulations (OC6.6) do not outline procedures for disabling LFDD operation when the protected region of the relay is exporting. New section(s) and Clause(s) will therefore need to be added to OC6.6 before this solution can be deployed. ▪ Policy need to be created to accommodate the use of the directional overcurrent relay's power flow indicators to determine power flow direction to create common best practice. ▪ Arrangements for policy detailing relay settings will need to be updated to capture the process of deactivating relays using power flow measurements from the directional overcurrent relay.
Financial	▪ Minimal investment is required to deploy this solution. Costs are related to the replacement of existing relays that do not have the required TRL and the cost the generate & install new settings for the relays. ▪ Solution could be deployed in short-term (approx. 2-4 years) given the limited financial and TRL barriers. It is dependent on the replacement of relays, successful use of overcurrent relays for power flow direction, and updated regulation & policy.
Organisational	▪ Alternative design is ideal for areas with high penetrations of DG and is applicable across all LFDD protection relays and sites, providing it has a modern digital relay with the required functions. ▪ Likely no changes to current responsibilities of WPD or NG ESO. There will need to be regulation and policy changes to be considered before and during deployment of the alternative design.

	▪ This solution is dependent on the successful trialling and use of the power flow indicator of directional overcurrent relays. This will require internal policy changes before deployment.
System Related	▪ Reliability of LFDD schemes will be marginally impacted by this alternative design given its use of proven technology and existing infrastructure. The use of directional overcurrent relay's power flow indicators to determine power flow direction may impact its reliability. ▪ Complexity of the scheme is minimally impact existing equipment; the use of directional overcurrent relays does increase the complexity.

4.3.2 RELOCATION OF LFDD RELAYS TO LOWER VOLTAGES WITH DISABLING DURING POWER EXPORT FUNCTIONALITY

The barriers to overcome for the *"Relocation of LFDD Relays to Lower Voltages with disabling during power export functionality"* alternative solution have been identified in Table 4-4.

Table 4-4 - Identified implementation barriers for Relocating LFDD Relays to Lower Voltages with Disabling Power Export Functionality

Source of Barrier	Key Considerations
Technological	▪ Moderate TRL given the challenges arising from the new configurations needed when relocating to lower voltages as well as the relay disabling settings and measurement of power flow direction. ▪ Most existing LFDD digital relays integrate blocking and sophisticated monitoring with communication capabilities. Equipment produced by OEM's have the TRL required for this solution. Relays that do not have these capabilities presents a barrier to overcome. This solution will also require the trialling of directional overcurrent relays. ▪ New settings are needed for the LFDD relays that deactivate them when reverse power flow is detected. This remains an important barrier to overcome for successful deployment. ▪ A key barrier of this solution is the relocation to lower voltages. Although the technology required to do this very mature (using existing and proven relays/systems) modification will be required to existing substations to accommodate the changes in configuration. ▪ In addition, it will be important for WPD to modify the procurement process for LFDD relays to include only equipment that can provide the capabilities required for disabling on power export.
Regulatory and Policy	▪ The relocation of LFDD relays to lower voltages aspect of the solution complies with the existing Grid Code OC6.6 requirements. However, New section(s) and Clause(s) to OC6.6 are required before this solution can be deployed for the disabling of relays aspect of the solution. ▪ Policy changes may need to be made to capture the new lower voltage LFDD configuration to outline best practice, especially for sites which have limited space for extra equipment.

	▪ This solution requires use of the directional overcurrent relay's power flow indicators to determine power flow direction. This is not yet common practice for LFDDs and would require policy changes. ▪ Policy arrangements regarding the programming of settings of LFDD relays will also need to be updated to capture the processes for the relay to take the power flow measurements and send a control signal to deactivate the relay when the protected area is exporting.
Financial	▪ The large cost associated with this re-design in comparison to the short-term solutions resulted in the its reclassification to a medium-term alternative option. This is directly related to large upfront labour costs to design the scheme, create new relay settings, reconfigure substations, and procure new relays for sites where relays do not have the required functionality for disabling on power export. ▪ Solution could be deployed in near medium-term (approx. 5-7 years) however given the number of configuration changes to existing substations and the extra interconnection of equipment may lead to increased timeframes. This is also highly dependent on the successful use of directional overcurrent relays to detect reverse power flow.
Organisational	▪ This solution is ideal for areas with high penetrations of DG and for areas with ANM schemes where constraints can be implemented on DG and ensure continued power production to support frequency restoration without local voltage saturation from disconnected load. ▪ Alterations may be need for sites where space is limited (substation top boxes, or extensions) to accommodate the scale of configuration and interconnection of equipment. It is also important to ensure substations are equipped with modern digital relays with the required functions. ▪ There will likely be minimal changes to the current responsibilities of DNOs or NG ESO. There will however need to be regulation and policy changes before and during deployment of the alternative design, specifically for the use of directional overcurrent relays and definition of best practice for the reconfiguration of substations sites.
System Related	▪ System reliability and risk of failure could be impacted by the reconfiguration and greater interconnection of equipment at substations given its novelty. Relocation to lower voltages has been well understood in theory by risks are presented in the transition to BaU. ▪ Reliability of schemes may also be affected by the use of directional overcurrent relays to determine power flow direction and should be key consideration before deployment. ▪ The reconfiguration of substations and use of directional overcurrent relays adds complexity to the LFDD system, however the use of proven equipment helps to mitigate this. This system does not require complex control algorithms, complex communications, or data exchanges.

5 REFERENCES

[1] Energy Emergencies Executive Committee (E3C), "GB power system disruption on 9 August 2019," Department for Business, Energy & Industrial Strategy (BEIS), London, 202.

[2] Western Power Distribution, "Distribution System Operability Framework," WPD, Bristol, 2018.

[3] H. Seyedi et. al, "Design of New Load Shedding Special Protection Schemes for a Double Area Power System," *American Journal of Applied Sciences,* vol. 6, no. 2, pp. 317-327, 2009.

[4] NG ESO and WPD, "SHEDD Innovation Project, Deliverable D3.1: Shortlisting of Alternative LFDD Re-design Option," 2020.

[5] NG ESO and WPD, " SHEDD Innovation Project, Deliverable D4.2: Modelling and Assessment of Shortlisted Low frequency Demand Disconnection Options," 2021.

[6] National Grid Electricity System Operator, "The Grid Code Issue 5 Revision 47," NG ESO, Great Britain, 24 December 2020.

[7] NG ESO and WPD, "SHEDD Innovation Project, Deliverable D1.1: An Overview of the LFDD Scheme and Recommendations for Future Improvements," 2020.

[8] NG ESO and WPD, "SHEDD Innovation Project, Deliverable D4.1: Modelling Methodology for Alternative LFDD Scheme," 2020.

[9] NG ESO and WPD, "SHEDD Innovation Project, Deliverable D2.2: Consumer Impact in LFDD Scheme," 2020.

[10] ABB, "SPAF 140C Frequency Relay User's manual and technical description," [Online]. Available: https://library.e.abb.com/public/450c789630bc3171c2256bf0004cbc62/FM_SPAF140C_EN_CDA.pdf.

[11] Siemens, "Load Shedding (7RW80) Application Notes," [Online]. Available: https://new.siemens.com/global/en/products/energy/energy-automation-and-smart-grid/protection-relays-and-control/siprotec-compact/voltage-and-frequency-protection/voltage-and-frequency-protection-siprotec-7rw80.html.

[12] GE, "DFF Digital Frequency Relay Brochure," [Online]. Available: https://www.gegridsolutions.com/products/brochures/dff.pdf.

[13] Western Power Distribution, "Low Frequency Demand Disconnection," WPD, 2018.

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