SPM 6.6kV Network Groups Fault Level Mitigation

ED2 Engineering Justification Paper

ED2-LRE-SPM-008-CV3-EJP

Issue	Date	Comments
Issue 0.1	Apr 2021	Issue to SRG and external assurance
Issue 0.2	May 2021	Reflecting comments from SRG
Issue 0.3	Jun 2021	Reflecting assurance feedback
Issue 1.0	Jun 2021	Draft Business Plan Submission
Issue 1.1	Oct 2021	Reflecting updated DFES forecasts
Issue 1.2	Nov 2021	Reflecting updated CBA results
Issue 2.0	Dec 2021	Final Business Plan Submission

Scheme Name	SPM 6.6kV Network Groups Fault Level Mitigation		
Activity	Voltage uprating of 6.6kV network groups		
Primary Investment Driver	Fault Level Mitigation		
Reference	ED2-LRE-SPM-008-CV3-EJP		
Output	Fault Level		
Cost	£5.962m		
Delivery Year	2024-2028		
Reporting Table	CV3		
Outputs included in ED1	~~Yes~~/No		
Business Plan Section	Develop the Network of the Future		
Primary Annex	Annex 4A.2: Load Related Expenditure Strategy: Engineering Net Zero Annex 4A.6: DFES		
Spend Apportionment	**ED1**	**ED2**	**ED3**
	-	**£5.962m**	**-**

SP ENERGY NETWORKS

Technical Governance Process

Project Scope Development

IP1(S)

To be completed by the Service Provider or Asset Management. The completed form, together with an accompanying report, should be endorsed by the appropriate sponsor and submitted for approval.
IP1 – To request project inclusion in the investment plan and to undertake project design work or request a modification to an existing project
IP1(S) – Confirms project need case and provides an initial view of the Project Scope
IP2 – Technical/Engineering approval for major system projects by the System Review Group (SRG)
IP2(C) – a Codicil or Supplement to a related IP2 paper. Commonly used where approval is required at more than one SRG, typically connection projects which require connection works at differing voltage levels and when those differing voltage levels are governed by two separate System Review Groups.
IP2(R) – Restricted Technical/Engineering approval for projects such as asset refurbishment or replacement projects which are essentially on a like-for-like basis and not requiring a full IP2
IP3 – Financial Authorisation document (for schemes > £100k prime)
IP4 – Application for variation of project due to change in cost or scope

PART A – PROJECT INFORMATION

Project Title:	SPM 6.6kV Network Groups Fault Level Mitigation
Project Reference:	ED2-LRE-SPM-008-CV3-EJP
Decision Required:	Concept approval for fault level mitigation in 6.6kV network groups by uprating to 11kV voltage.

Summary of Business Need:

SP Manweb (SPM) operates the distribution system with standard voltage levels of 132kV, 33kV (EHV), 11kV (HV) and 400/230V(LV). Few of the 6.6kV groups are currently experiencing fault level issues (under intact/normal running conditions) and operationally managed to keep the fault levels within switchgear / design limits. Due to the significant growth in distributed generation, it is anticipated that the fault levels on these already constrained networks will exacerbated in the RIIO-ED2 period. Often these groups operate with primary transformers on open-standby, resulting in an underutilised asset and also reduction in the thermal capacity. The proposed conventional solution is to uprate the 6.6kV groups to 11kV in SPM area to facilitate additional thermal and fault level headroom uplift, network operational efficiencies and reduction in network losses. The following 6.6kV groups are currently experiencing fault level issues and identified to be uprated to 11kV voltage level to mitigate the fault level issues.

- Bentinck Street / Chester Street and MDHB Egerton Dock
- British Sidac / Sherdley Road / St Helens Linkway / Watery Lane
- Gilbrook Dock / Hill Road / Mobil oil (Wallasey)

Summary of Project Scope, Change in Scope or Change in Timing:

1. Replace the non-standard single voltage plant equipment such as primary, secondary transformers and voltage measurement transformers with dual ratio ones to operate at 11kV voltage.
2. Refurbish the HV oil CBs and install with tele-control to provide operational flexibility.

The estimated cost for the above is **£5.962m** (in 2020/21 prices) under CV3 with 100% contribution to be included in the ED2 load related expenditure. The proposed uprating scheme will create additional fault level headroom of 100MVA and provide and additional infeed of 7.5/10MVA in each group.

Expenditure Forecast (Where available based on Regulatory Allowance – 2020/21)

Licence Area	Reporting Table	Description	Total (£m)	Incidence (£m)				
				2023/24	2024/25	2025/26	2026/27	2027/28
SPM	CV3	Fault Level Reinforcement	**5.962**	1.012	1.394	1.488	1.181	0.886
		Total Expenditure within RIIO-ED2	**5.962**					

PART B – PROJECT SUBMISSION

Proposed by	Ramesh Pampana	Signature	[signature]	Date:	30/11/2021
Endorsed by	Russell Bryans	Signature	[signature]	Date:	30/11/2021

PART C – PROJECT APPROVAL

Approved by	Malcolm Bebbington	Signature	[signature]	Date:	30/11/2021

Contents

1 Introduction

SP Manweb (SPM) distribution network operates at standard voltage levels of 132kV, 33kV(EHV), 11kV(HV) and 400/230V(LV). A small proportion of legacy SPM network operates at 6.6kV voltage level, predominantly in urban areas, operated as interconnected groups of two or more primary substations, often the number of interconnected groups is limited by the fault level limits. The design fault level limit of these 6.6kV group is 150MVA and those 6.6kV network groups, with more than 2 primary transformer infeeds, are currently being operated with at least one primary transformer on open-standby i.e., these groups are run in depleted state continually.

Further these 6.6kV networks result in constrained system thermal and fault level capacities, higher network losses, additional reinforcement needs due to limited capacity compared to their 11kV equivalents. The diminishing population of 6.6kV plant also presents risks from the perspective of fault repairs and availability of spares.

The proposed solution is to uprate the following three 6.6kV operated groups to 11kV to facilitate additional thermal and fault level headroom uplift, network operating efficiencies and significant reduction in network losses. The following are the 6.6kV groups included the voltage uprating scheme:

- Bentinck Street / Chester Street and MDHB Egerton Dock
- British Sidac / Sherdley Road / St Helens Linkway / Watery Lane
- Gilbrook Dock / Hill Road / Mobil oil (Wallasey)

The estimated cost for the above is £5.962m (in 2020/21 prices) with 100% contribution to be included in the ED2 load related expenditure. The works are proposed to start in 2023/24 and finish by 2025/26 In both British Sidac and Gilbrook Dock group. For the Bentinck Street and MDHB Egerton Dock group, the works are proposed to start in 2025/26 and finish by 2027/28. The proposed uprating scheme will create additional fault level headroom of 100MVA and facilitates to run the group in intact state by bringing the open-standby transformer into service, which gives an additional infeed of ca. 7.5/10 MVA in each group by the end of ED2 period.

2 Background Information

2.1 Existing/Authorised Network

2.1.1 Bentinck Street / Chester Street & MDHB Egerton Dock

The Bentinck Street / Chester Street & MDHB Egerton Dock 6.6kV groups are fed from the upstream Prenton – Rock Ferry 33kV group; operated split at Marshall Street, Chester Street and Cammel Laird North primary substations. The Bentinck Street / Chester Street group is supplied via 3 x 7.5MVA primary transformers two at Bentinck Street and one at Chester Street, one of the Bentick St primary transformer is operated on open-standby due to fault level issues in the group. The MDHB Egerton Dock group is fed by 2 primary transformers, 7.5MVA and 10MVA rated.

The Bentinck Street / Chester Street 6.6kV supplies to ca. 6435 customers via 48 secondary substations and 3 HV customers. The MDHB Egerton Dock group supplies to 359 customers via 22 secondary substations and 6 HV customers. The group's connectivity and primary substation locations are shown in Figure 8-1 and Figure 8-2 in Appendix A.

2.1.2 British Sidac / Sherdley Road / St Helens Linkway / Watery Lane

The British Sidac / Sherdley Road / St Helens Linkway / Watery Lane 6.6kV group is fed from are fed from the Ravenhead – St Helens 33kV group by 4 x 7.5MVA primary transformers at each primary substation, the one at St Helens Linkway is operated on open-standby due to fault level issues. The group supplies to ca. 5106 customers via 43 secondary substations and 5 HV customers. The group's connectivity and primary substation location is shown in Figure 8-3 and Figure 8-4 in Appendix A.

2.1.3 Gilbrook Dock / Hill Road / Mobil oil (Wallasey)

The Gilbrook Dock / Hill Road / Mobil oil (Wallasey) 6.6kV group is fed from are fed from the Wallasey-Woodside by 3 primary transformers at each primary substation, the one at Hill Road is operated on open-standby due to fault level issues. The group supplies to ca. 6115 customers via 42 secondary substations and 65 HV customers. The group's connectivity and primary substation location is shown in
Figure *8-5* and Figure 8-6 in Appendix. A

2.2 Network supply / circuit capacity

All the 6.6kV groups are currently are classed as P2/7 Group B (≥1MW and <12MW). Table 3-1 presents the existing network supply capacity of the 6.6kV groups in consideration.

Table 2-1: Summary of authorised EHV group network

HV group	Customers (#)	Outage Scenario	LI Firm Capacity (MVA)	Group demand (MVA)	Load Index	EREC P2/7 Class
BENTINCK STREET T1 / BENTINCK STREET T2 / CHESTER STREET T1	6,073	N-1	18.2	10.5	LI1	B
MDHB EGERTON DOCK T1 / MDHB EGERTON DOCK T2	319	N-1	9.1	6.1	LI1	B
BRITISH SIDAC T1 / SHERDLEY ROAD T1 / ST HELENS LINKWAY T1 / WATERY LANE T1	5052	N-1	18.2	8.4	LI1	B
GILBROOK DOCK T1 / HILL ROAD T1 / MOBIL OIL (WALLASEY) T1	6,186	N-1	18.2	12.7	LI1	B

2.3 Embedded Generation

There is no HV connected embedded generation in any of the groups due to the existing fault level issues.

2.4 Fault levels

The current 6.6kV networks design fault level limits are 150MVA / 13.12kA (RMS Break). The upstream 33kV network fault level design limits are 1000MVA/17.5kA for modern switchgear substations and 750MVA/13.12kA for legacy switchgear substations.

The fault levels on the 6.6kV network group is determined by,

- Fault level on the primary substation 33kV nodes.
- Number of primary transformers operating parallel in the group.
- Generation / Demand(G74) fault level contributions

The primary transformers in SPM are rated for 7.5/10MVA, with 10% impedance. For a maximum design fault level limit of 750/1000MVA at the 33kV level, the maximum fault level infeed through the primary transformer will be ca. 68-70MVA. As such the number of fault infeeds i.e., the number of primary transformers operating in parallel in a group determines the fault levels on the 6.6kV network.

For groups with more than two primary transformers infeeds, depending on the 6.6kkV circuit impedances , the fault levels will be close to the design limits of the 150MVA.Further, the fault contributions from the generation and demand (G74) connected within the group will add to the fault infeeds. Table 2-2 shows the calculated 33kV fault levels and estimated 6.6kV fault levels at each of the primary substation in the respective groups. As seen, the cumulative fault levels at the 6.6kV nodes are very likely to have fault level exceedances due to the multiple infeeds under intact running arrangements.

Table 2-2: 33kV Fault Levels of each primary group

33kV Group	HV Group	Primary Substation Name	RMS Break Fault Level (MVA)	
			33kV	6.6kV#
BOLD / RAVENHEAD / ST HELENS	BRITISH SIDAC T1 / SHERDLEY RD T1 / ST HELENS LINKWAY T1 / WATERY LANE T1	St Helens Linkway*	489	65
		Sherdley Road	649	67
		Watery Lane	636	67
		British Sidac	634	67
PRENTON / ROCK FERRY	BENTINCK ST T1 & T2 / CHESTER ST T1	Bentinck Street A*	501	65
		Bentinck Street B	501	65
		Chester Street	469	69
	MDHB EGERTON DOCK T1 & T2	MDHB Egerton Dock A	466	65
		MDHB Egerton Dock B	466	65
WALLASEY / WOODSIDE	GILBROOK DOCK T1 / HILL RD T1 / MOBIL OIL (WALLASEY) T1	Mobil Oil (Wallasey)	734	68
		Gilbrook Dock	670	67
		Hill Road*	646	67
# Estimated fault infeed from each of primary transformer * Primary transformer operated on open-standby				

3 Needs Case

In SPM, majority of the HV network is operated at 11kV voltage level, with few patches of the network operated at non-standard 6.6kV voltage level, which accounts for up to 10% of the total HV group population. These non-standard voltage networks can result in constrained system capacity, additional reinforcement needs (e.g. 6.6kV cables overload before their 11kV equivalents) and incremental costs for dual ratio equipment for plant installations.

The 6.6kV network, when compared to the 11kV equivalents, have the inherent issues like:

1. Constrained system thermal headroom – The maximum transformer infeed is limited to 9.1MVA (due switchgear limitation), compared 10MVA (primary transformer cyclic loading limit) on 11kV networks.
2. Constrained system fault level headroom – The fault levels limits are 150MVA compared to 250MVA on 11kV network, the additional 100MVA headroom is the result of voltage upscaling of 1.67 times.
3. Higher network losses - The losses are typically 2.78 times higher compared to the 11kV network, due to higher current flows.
4. Require additional reinforcement needs due to limited (thermal / fault level) capacity as well as the incremental cost to the customers for installing dual-ratio equipment.
5. The diminishing population of 6.6kV equipment also presents risks from the perspective of fault repairs and availability of spares.

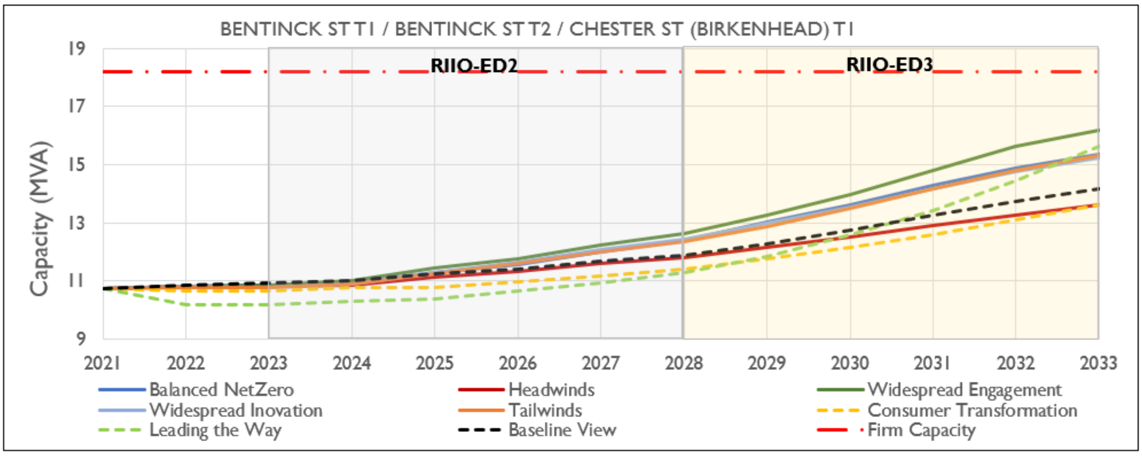
Additionally, few of the 6.6kV primary substations operate with legacy switchgear, do not have tele-control for remote switching operations, requires manual switching during outages/abnormal conditions on the network does not provide the operational flexibility.

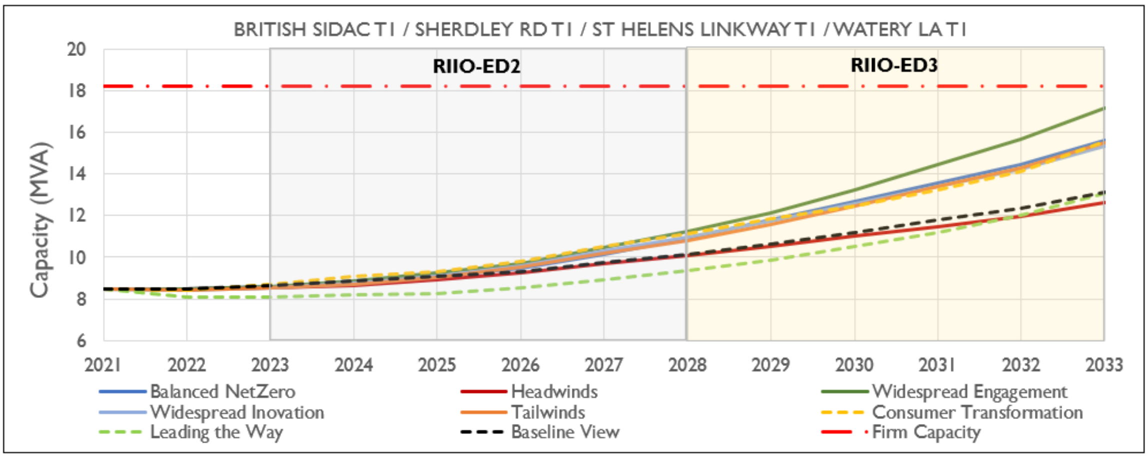
The perpetuated operation of these 6.6kV groups is becoming challenging with the demand/generation growth and offers very little to no headroom for the prospective customers. Therefore, an overarching solution is necessary to address the fault level constraints, increase the network thermal/fault level capacity, reduce the network losses, increase operational efficiency and reduce the overall network operational costs.

3.1 Distribution Future Energy Scenarios

3.1.1 Forecast Demand

The DFES forecast is based on actual system measurement data from the PI system and stakeholder endorsed Distribution Future Energy Scenarios (DFES) and considers our pipeline of known developments. The winter demand forecast based on the future energy scenarios along with the projected demand from authorised connections is shown in Figure 3.1. The demand forecast for the RIIO-ED2 period is within the firm capacities of each of the individual group.





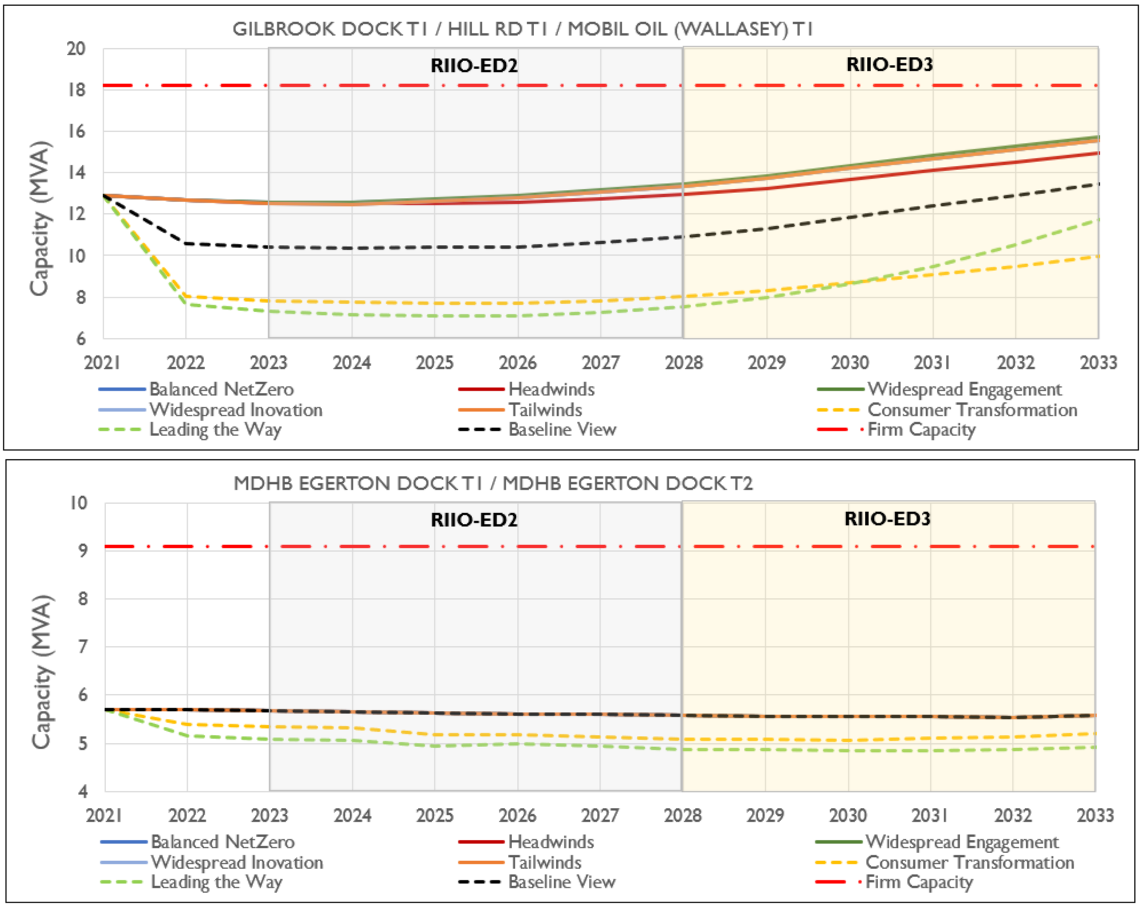


Figure 3-1: Demand forecast for each of the group

3.2 Network Impact Assessment

The 6.6kV groups have been assessed with the forecast demand growth, covering thermal and fault level considering the different demand forecast scenarios. The findings from the network impact assessments are detailed in sections below.

3.2.1 Thermal Constraints

No additional thermal constraints in the network groups under intact and outage conditions with the forecast demand.

3.2.2 Fault Level Constraints

The fault level issues in each of the groups will remain and perpetuate into RIIO-ED2, likely exacerbate with the connection of new generation on the upstream networks and require operational measures to manage the fault level exceedances. Within each of the groups, the DFES generation forecast is not significant over the RIIO-ED2 period.

4 Optioneering

Table 4-1shows a longlist of the options considered for this reinforcement. Few of the longlist options are rejected based on the technical and commercial rustications, the reasons are provided. The shortlisted options are taken forward for detailed analysis and included in the cost-benefit analysis. The baseline option represents the lowest cost conventional option, i.e. the minimum level of intervention to mitigate the fault level issues.

Table 4-1: Summary of the options

	Option	Status	Reasons for rejection
(a)	Do Nothing	Rejected	Leads to perpetuation of 6.6kV networks; Limited thermal / fault level headroom, deter new demand and generation connections, higher network losses and does not offer operational and maintenance efficiencies.
(b)	Intervention plan using only Energy Efficiency	Rejected	Rejected as it does not address the network fault level issues.
(c)	Replant with higher rated switchgear	Rejected	This option does not provide any additional benefit, as the network is constrained due to the design fault level limits.
(d)	Replace the primary transformers with higher impedance transformers.	Considered (**Baseline**)	
(e)	Voltage uprating to 11kV	Considered (**Option 1**)	
(f)	Voltage uprating to 11kV with network transition	Considered (**Option 2**)	
(g)	Series reactors	Rejected	This option is discarded based on additional civil costs and space constraints and leads to perpetuated operation of 6.6kV networks. The series reactors introduce additional losses and require additional equipment for mitigating switching transient voltages.
(h)	Active fault level management and monitoring.	Rejected	This option cannot address the existing fault level issues and does not provide any operational benefits, as the exceedances are already being operationally managed.
(i)	Split the networks groups	Rejected	This option can result in islanded network groups during outages. Also reduces the security of supply, due to the reduced thermal level headrooms.

5 Detailed Analysis

5.1 Option 1 (Proposed): Voltage uprating to 11kV

The proposed scheme is an overarching solution, besides increasing the fault level headroom, the solution offers additional benefits of thermal headroom uplift, technical losses reduction, improves operational flexibility and reduces the overall network operating costs.

The proposed conventional solution involves uprating the three 6.6kV network groups to 11kV. Prior to the changeover, the existing 33/6.6kV and 6.6kV/LV substations will be converted to dual ratio sites (where not already) and thereafter migrated over to 11kV operation.

It should be noted that few of the customers in each of the groups, fed directly from the 6.6kV network. This will be their preferred choice of connection and will remain unchanged until such times as their own requirements trigger an application for change. As, part of the proposed scheme, it is recommended an early engagement with these customers to progress the scheme.

5.1.1 Scope of works

<u>Bentinck St / Chester St & MDHB Egerton Dock groups</u>

With uprating of Bentinck Street / Chester Street 6.6kV group alone, the MDHB Egerton Dock will be an isolated 6.6kV primary group, will be under the potential risk of security of supply with just two infeeds and also loses the flexibility of interconnecting the groups under abnormal operating conditions. Therefore, for these reasons, it is cost effective to uprate the MDHB Egerton Dock along with Bentinck Street / Chester Street group.

Please note that, Cammel Laird North primary substation operates split from Bentinck Street / Chester Street group, currently feeds on single customer and is interconnected with Cammel Laird South site through customer 6.6kV network. With the Bentinck Street / Chester Street group uprated to 11kV, the Cammel Laird North primary substation, will operate split but loses the facility to interconnect.

The proposed works under the uprating these two groups are:
Primary substation works:

- Replace the single ratio 6.6kV primary transformers with dual ratio transformers - 2 x Bentinck St., 1 x Chester St., 2 x MDHB Egerton Dock.
- Retrofit the existing HV oil CBs with vacuum units and tele-control - 9 x Bentinck St, and 11 x MDHB Egerton Dock.
- Replace the single ratio VTs with dual ratio units – 12 (in total).

Secondary substations work:

- Replace the 6.6kV / LV single ratio secondary transformers with dual ratio transformers – 28 out 48 in Bentinck St group, 12 out of 22 in MDHB Egerton Dock group.

With the proposed uprating solution, fault level limit increases to 250MVA in both the groups. The firm capacity increases to 20MVA in the Bentinck Street / Chester Street group and the Bentick St primary transformer can be operated in service as normal running arrangement. In the MDHB Egerton Dock group, the fault level limit increase to 250MVA and the firm capacity increases to 10MVA.

British Sidac / Sherdley Road / St Helens Linkway / Watery Lane group

The proposed works under the uprating these in the group are:
Primary substation works[1]:

- Replace the single ratio 6.6kV primary transformers with dual ratio transformers - 2 x Watery Lane., 1 x Sherdley Road.
- Retrofit the existing HV oil CBs with vacuum units and tele-control - 11 x Sherdley Road
- Replace the single ratio VTs with dual ratio units – 14 (in total).

Secondary substations work:

- Replace 6.6kV / LV single ratio secondary transformers with dual ratio transformers – 19 x ground mounted, 2 x pole mounted, 21 out of 43 in total, the rest are dual ratio.

With the proposed uprating solution, fault level limit increases to 250MVA and the firm capacity increases to 30MVA and the St Helens Linkway primary transformer can operate in-service as normal running arrangement.

Gilbrook Dock / Hill Road / Mobil Oil (Wallasey) group

The proposed works under the uprating these in the group are:

[1]Watery Lane HV switchboard (x9) is being refurbished under CV7 in RIIO-ED2.

Primary substation works[2]:

- Replace the single ratio 6.6kV primary transformers with dual ratio transformers - 1 x Gilbrook Dock., 1x Hill Road.
- Retrofit the existing HV oil CBs with vacuum units and tele-control - 8 x Gilbrook Dock.
- Replace the single ratio VTs with dual ratio units – 10 (in total).

Secondary substations work:

- Replace 6.6kV / LV single ratio secondary transformers with dual ratio transformers – 28 x ground mounted, 21 out of 42 in total, the rest are dual ratio.

With the proposed uprating solution, fault level limit increases to 250MVA and the firm capacity increases to 20MVA and the Hill Road primary transformer can operate in-service as normal running arrangement.

5.1.2 Technical Losses Reduction

With the proposed uprating scheme, the network groups also benefit from the reduction of technical losses. In theory, uprating to 11kV can reduce the losses as much as 2.78 times compared to 6.6kV networks, which gives significant savings over the lifetime of the assets and thereby contributing to reduction in CO_2 emissions. The combined losses reduction post uprating in all the groups is calculated to be 3.12GWh/year by end of 2028 period and considered to be same over the next 45 years.

For the cost-benefit analysis of the proposed scheme, the reduction in technical losses are considered under societal benefits which increases the net present value of the scheme compared to the baseline option.

5.1.3 Overall Scheme Costs

Table 5-1shows the cumulative cost and volumes breakdown of the assets under the proposed scheme. The detailed cost and volumes breakdown for each of the primary substation is given in Appendices - 8.1to 8.3 The assets identified are currently single ratio units, under the proposed scheme they will be replanted with dual ratio units for the purpose of uprating.

Table 5-1: Cost breakdown for Option 1

Asset Description	Volumes	Unit Cost (£m)	Prime Costs (£m)
33kV Transformer (GM)	10	0.314	3.144
6.6/11kV Transformer (GM)	98	0.015	1.421
6.6/11kV Transformer (PM)	2	0.006	0.012
6.6/11kV CB(GM) Primary - Refurb	30	0.019	0.575
HV VT replacement	42	0.005	0.210
Civil Works at 33 kV & 66 kV Substations	-	-	0.600
		Total Costs (£m)	**5.962**

5.2 Option 2 (Rejected): Voltage uprating to 11kV with network transitioning

This option, in addition to the voltage uprating to 11kV, considers the opportunity of network transitioning i.e., conversion of X-Type substations to Y-Type. The X-Type substations feed interconnected networks, while the Y-substations are run radially. The costs of X-Type networks are greater than a typical Y-Type(radial) networks due to the bespoke unit protection equipment, including

[2] Mobil Oil(Wallasey) HV switchboard (x7) is being replaced under CV7 in RIIO-ED2.

pilot wires, protection panels, batteries, LV circuit breakers and additional civil costs of brick-built substations. On the other hand, Y-Type networks are relatively low cost, but are prone to higher customer interruptions compared to X-Type networks.

The prime driver for the network transition is based on SPM's long-term strategy to develop the network to facilitate a low carbon future and to provide optimal network benefits whilst minimising network cost (see Interconnected Network Transitioning Policy, ESDD-01-013 and Annex 4.48: SPM Company Specific Factors of our ED2 Business plan). The transitioning policy outlines that network transitioning opportunity should be explored on a case-by-case basis and to be implemented where the overall benefits of the transition outweigh the benefits offered by the interconnected networks. The transition criteria applies to networks where there is low level of LV interconnection, feeders with X & Y Type substations mix (Y-Type >=50%), majority of asset base in poor health(e.g. HI5) and voltage uprating schemes etc.

As the voltage uprating encompasses interventions for whole of the network groups in consideration, it provides an opportunity of assessing the benefits offered by transitioning in addition to the voltage uprating. For each of the 6.6kV network groups, the X & Y-Type substation proportions are analysed and shown in Table 8-7. As seen, except for British Sidac / Sherdley Road / St Helen's Linkway /Watery Lane 6.6kV group, the rest of the networks are mostly X-Type and those with higher X-type proportions are considered for transitioning. It should be noted that the transitioning will often will lead to increase in customer interruptions relatively, however the CI/CML performance of the Y-Type networks can be matched to that of X-Types by network automation though directional fault passage indicators (dFPIs) and Smart LV sectionalisers. The capital expenditure (Capex) costs involved in the transitioning as well as the operational expenditure (Opex) savings post transitions are considered as follows:

- Capex cost of X-Type to Y-Type conversion - £10k / substation
- Capex savings from newly built Y-Type substations - £60k / substation
- Opex savings of converted X-Type substations - £152 / substation / year
- Opex savings from newly built Y-Type substations - £452/substation / year
- Cost of increased CI / CMLs post transition – included under societal benefits

The above costs are in addition to the voltage uprating costs of installing dual-ratio equipment as mentioned in Option-1 and the calculations are detailed in the CBA working sheets for Option-2. The scheme also carries similar benefits in losses as reduction as mentioned in section 5.1.2. As with the proposed uprating solution, this option also creates additional fault level and thermal headroom in all the 6.6kV groups in consideration. Table 5-2 shows the cumulative cost and volumes breakdown of the assets under the proposed scheme.

Table 5-2: Cost breakdown for Option 2

Asset Description	Volumes	Unit Cost (£m)	Prime Costs (£m)
33kV Transformer (GM)	10	0.314	3.144
6.6/11kV Transformer (GM)	98	0.014	1.421
6.6/11kV Transformer (PM)	2	0.006	0.012
6.6/11kV CB(GM) Primary - Refurb	30	0.019	0.575
HV VT replacement	42	0.005	0.210
X-Type to Y-Type Conversion	92	0.010	0.920
Civil Works at 33 kV & 66 kV Substations	-	-	0.600
		Total Costs (£m)	**6.822**

5.3 Baseline Option (Rejected): Higher impedance primary transformers.

The baseline solution considers the perpetuated operation at 6.6kV voltage level, however in order to mitigate the fault levels, it is proposed to replant the existing primary transformers with higher impedance units thereby reducing the fault infeed into the 6.6kV groups. The higher impedance primary transformers will be of bespoke design, can cost higher (assumed to 10% higher) than the BaU units.

For the baseline solution, excluding the MDHB Egerton Dock group, the groups with existing fault level issues are considered for primary transformer replanting. A total of 10 primary transformers across the three groups are proposed to be replaced with higher impedance units(13% impedance compared to standard 10% impedance), the impedance value is chosen to limit the voltage step change on the network during the primary transformer switching. As such this option creates limited additional fault level and thermal headroom in all the 6.6kV groups in consideration, and it is expected that the 6.6kV groups needs to be uprated to 11kV by the end of RIIO-ED3 period to

Table 5-3: Cost breakdown for Baseline option

Asset Description	Volumes	Prime Costs (£m)
33kV Transformer (GM)	10	3.144
Civil Works at 33 kV & 66 kV Substations	-	0.600
Additional cost of bespoke high impedance units	-	0.314
Total Costs (£m)		**4.058**

5.4 Options Cost Summary Table

Summary of the costs for each of the evaluated options is presented in Table 5-4.

Table 5-4: Technical summary for considered options

Options	Summary	RIIO-ED2 Cost (£m)
Baseline	Replace the primary transformers with higher impedance units.	4.058
Option 1	Voltage uprating to 11kV	5.962
Option 2	Voltage uprating to 11kV and network transitioning	6.882

Derivation of costs for these options are based on the SPEN RIIO-ED2 Unit Cost Manual for intervention. This is based on bottom up cost assessment of the components of activity detailed within the RIGs Annex A for the above activities, SPEN's contractual rates for delivery, market available rates and historic spend levels.

6 Deliverability & Risk

6.1 Preferred Options & Output Summary

The adopted option is, Option 1 to uprate the 6.6kV network groups to 11kV. Th adopted option is an overarching solution facilitating additional thermal and fault level headroom uplift, network operating efficiencies and reduction in network losses.

6.2 Cost Benefit Analysis Results

A cost benefit analysis (CBA) was carried out to compare the NPV of the options discussed in the previous sections. Considering the lowest forecast capital expenditure, the proposed option has the highest total NPV and represents the optimal cost option when losses and other operational costs are included in the analysis. Based on the outcome of the CBA, the proposed option is to uprate the identified 6.6kV network groups to operate at 11kV voltage. The summary of the cost benefit analysis is presented in Table 6-1. The full detailed CBA is provided within 'ED2-LRE-SPM-008-CV3-EJP- SPM 6.6kV Network Groups Fault Level Mitigation'.

Table 6-1: Summary of Cost Benefit Analysis

Options Considered	Decision	Comment	NPVs based on payback periods from 2023/24 (£m)			
			10 years	20 years	30 years	45 years
Baseline – Replace the primary transformers with higher impedance units.	Rejected	Rejected based on the cost benefit analysis, the NPV diminishes over the long term compared to Option-1	0.00	0.00	0.00	0.00
Option 1 – Voltage uprating to 11kV	**Adopted**		0.07	0.85	1.32	1.82
Option 2 - Voltage uprating to 11kV and network transitioning.	Rejected	Rejected based on the cost benefit analysis, the network transitioning does not offer any additional cost benefit compared to Option 1.	-0.51	-0.07	0.20	0.53

6.3 Cost & Volumes Profile

Table 6-2 shows the breakdown of expenditure for the proposed scheme (in 2020/21 prices) and the cost incidence (in 2020/21 prices) over the RIIO-ED2 period is shown Table 6-3. The total cost of the proposed scheme is £5.962m.

Table 6-2: Cost breakdown for Option 1

Asset Description	Volumes	Prime Costs (£m)
33kV Transformer (GM)	10	3.144
6.6/11kV Transformer (GM)	98	1.421
6.6/11kV Transformer (PM)	2	0.012
6.6/11kV CB(GM) Primary - Refurb	30	0.575
6.6/11kV VT replacement	42	0.210
Civil Works at 33 kV & 66 kV Substations	-	0.600
Total Costs (£m)		**5.962**

Table 6-3: Cost incidence over the RIIO-ED2 period, £m (2020/21 Prices)

HV Group	Total (£m)	Incidence (£m)				
		2023/24	2024/25	2025/26	2026/27	2027/28
British Sidac / Sherdley Road / St Helens Linkway / Watery Lane	1.640	0.328	0.984	0.328	-	-
Bentinck St / Chester St & MDHB Egerton Dock	2.954	-	-	0.886	1.181	0.886
Gilbrook Dock / Hill Road / Mobil Oil (Wallasey)	1.368	0.684	0.410	0.274	-	-
Total Investment (Fault Level Reinforcement / CV3)	**5.962**	**1.012**	**1.394**	**1.488**	**1.181**	**0.886**

6.4 Risks

The voltage uprating schemes typically encompasses interventions across the entire network groups and can have longer lead delivery times. Currently, within the RIO-ED1 period, SPM has experience of voltage uprating and transitioning the Southport area's Banastre Rd / Dover Rd / Grantham Close 6.6kV network group, the learnings from delivering this scheme will help in delivering of the proposed scheme.

The proposed scheme has three 6.6kV network groups identified for voltage uprating, the timing and delivery of the scheme on the individual network group level is chosen to have minimum network impact, this could be further optimised at the detailed design stage. From the SPM's experience of voltage uprating schemes, we have decided that an early engagement with the all customers and particularly those connected to the 6.6kV voltage directly as this will be their preferred choice of connection and will remain unchanged until such times as their own requirements trigger an application for change.

6.5 Outputs Included in RIIO-ED1 Plans

There are no outputs expected to be delivered in RIIO-ED1 that are funded within this proposal.

6.6 Future Pathways – Net Zero

6.6.1 Primary Economic Driver

The primary driver for this investment is the fault level exceedances beyond the design limits in the three 6.6kV network groups; the perpetuated operation at 6.6kV voltage level resulting in thermal headroom limitations, higher losses and also stranded assets in the form open-standby transformers.

6.6.2 Payback Periods

The CBA indicates that a positive NPV result in all assessment periods (10, 20, 30 & 45 years) which are consistent with the lifetime of the intervention. Consumers benefit from reduced network connection costs immediately on completion of the project. Additionally, the reduction in network technical losses will result in significant cost savings and reduction in CO_2 emissions.

6.6.3 Sensitivity to Future Pathways

The network capacity and capability that results from the proposed option is consistent with the network requirements determined in line with the section 9 of the Electricity Act and Condition 21. Additionally, the proposed option is consistent with the SPEN's Distribution System Operator (DSO) Strategy and Distribution Future Energy Scenarios.

Table 6-4 shows cumulative volumes of electric vehicle and heat pump uptakes for the three network groups across a range of future pathways and Table 6-5 shows the sensitivity of the proposed solution and Table 6-6 shows the sensitivity of the proposed RIIO-ED2 expenditure against the full ranges of Net Zero complaint future pathways.

Table 6-4: Electric Vehicle and Heat Pump uptakes across a range of future pathways

End of RIIO-ED2	SPEN	DFES			CCC				
	Baseline	System Transformation*	Consumer Transformation	Leading the Way	Balanced Net Zero	Headwinds	Widespread Engagement	Widespread Innovation	Tailwinds
EVs	2006	1553	2,716	3,313	2,900	2006	3153	2875	2875
HPs	1451	802	1,934	1,756	1728	1309	1941	1763	1643

** Note: System Transformation is excluded from future pathways assessment as it does not meet interim greenhouse gas emission reduction targets.*

Table 6-5: Sensitivity of the proposed solution against future pathways

	RIIO-ED1				RIIO-ED2					RIIO-ED3				
Solution Requirements	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
Baseline					R^1									
Consumer Transformation					R^1									
Leading the Way					R^1									
Balanced Net Zero					R^1									
Headwinds					R^1									
Widespread Engagement					R^1									
Widespread Innovation					R^1									
Tailwinds					R^1									

R^1 – Voltage uprating to 11kV (proposed solution)

The proposed solution is robust across all pathways. As this is the minimum requirement to mitigate the fault levels in the group, it is likely not sensitive to the future pathways and is expected that proposed solution is required under all the future pathways. In all cases this solution is expected to endure beyond RIIO-ED3.

Table 6-6: Sensitivity of the proposed RIIO-ED2 expenditure

	Baseline	Uncertain
RIIO-ED2 Expenditure(£m)	5.962	-
Comment	Proposed option.	-

6.6.4 Asset Stranding Risks & Future Asset Utilisation

Electricity demand and LCT uptake are forecast to increase under all scenarios. The stranding risk is therefore considered to be low.

6.6.5 Losses / Sensitivity to Carbon Prices

Losses have been considered in accordance with License Condition SLC49 and the SP Energy Networks Losses Strategy and Vision to "consider all reasonable measures which can be applied to reduce losses and adopt those measures which provide benefit for customers".

Reasonable design efforts have been taken to minimise system losses without detriment to system security, performance, flexibility, or economic viability of the scheme. This includes minimising conductor lengths/routes, the choice of appropriate conductor sizes, designing connections at appropriate voltage levels and avoiding higher impedance solutions or network configurations leading to higher losses.

The adopted solution is found to be sensitive to the impact of the carbon cost of losses. The proposed solution will reduce the network losses in all the uprated groups to the tune of 3.12GWh per year.. Losses have been considered as part of this design solution and it has not been necessary to carry out any Losses justified upgrades.

6.6.6 Whole Systems Benefits

Whole system benefits have been considered as part of this proposal as the adopted solution provides the benefits of thermal, fault level headroom uplift, network operational efficiencies and reduction in losses. The capacity and capability of the preferred option is consistent with the provision of whole system solutions.

6.7 Sustainability and Environmental Considerations

6.7.1 Operational and embodied carbon emissions

The proposed scheme has the potential to impact on the embodied carbon resulting from the replacement of non-standard single voltage plant equipment such as primary, secondary transformers and voltage measurement transformers, and the retrofit of the existing switchgear with tele-control.

During the evaluation of the options associated with the voltage uprating scheme we have embedded within the CBA6, where data are available, an assessment of the embodied carbon and the associated carbon cost to inform our NPV evaluation.

It should be noted that the embodied carbon evaluation undertaken has only considered the manufacture and supply of materials. Further collaborative industry-wide work is planned for the RIIO-ED2 price review period to better understand the overall embodied carbon values including, for example installation and commissioning services, decommissioning and disposal activities as well as refurbishment opportunities. More information regarding this can be found in Section 3.1.2 of our Environmental Action Plan, Annex 4C.3: Environmental Action Plan, SP Energy Networks, Issue 2, 2021.

6.7.2 Supply chain sustainability

For us to take full account of the sustainability impacts associated of the Proposed scheme, we need access to reliable data from our suppliers. The need for carbon and other sustainability credentials to be provided now forms part of our wider sustainable procurement policy.

6.7.3 Resource use and waste

The proposed scheme will result in the consumption of resources and the generation of waste materials from end of life assets.
Where waste is produced it will be managed in accordance with the waste hierarchy which ranks waste management options according to what is best for the environment. The waste hierarchy gives top priority to preventing waste in the first instance, then preparing for re-use, recycling, recovery, and last of all disposal (e.g. landfill).

6.7.4 Biodiversity/ natural capital

The proposed scheme will only affect developed sites containing existing assets. Therefore, the impact on, and the opportunity to improve biodiversity and natural capital is expected to be minimal.

6.7.5 Preventing pollution

SPEN will always follow all relevant waste regulations and will make sure that special (hazardous) waste produced or handled by our business is treated in such a way as to minimise any effects on the environment.

6.7.6 Visual amenity

SPEN continually seeks to reduce the landscape and visual effects of our networks and assets but recognises that the nature of our substations makes it challenging to minimise their visual impact.

6.7.7 Climate change resilience

In addition to our efforts to minimise our direct carbon emissions in line with our net-zero ambitions, we are also conscious of the need to secure the resilience of our assets and networks in the face of a changing climate. We have also modified our policy on vegetation control in the face of higher temperatures and longer growing seasons

The project will take account of sustainability initiatives that are relevant to this site and reflect wider licenced business sustainable development objectives set out in the Environmental Action Plan. The project will avoid environmental impacts where possible and provide mitigation and improvements when required, and all relevant environmental and planning consents will be secured.

7 Conclusion

Few of the 6.6kV network groups are fault level constrained and currently operationally managed to mitigate the fault level exceedances. Due to the significant growth in distributed generation, it is anticipated that the fault levels in the already constrained networks will exacerbated in the RIIO-ED2 period. Further these 6.6kV networks result in constrained system thermal and fault level capacities, higher network losses, additional reinforcement needs due to limited capacity compared to their 11kV equivalents. The diminishing population of 6.6kV plant also presents risks from the perspective of fault repairs and availability of spares

The proposed scheme is an overarching solution, beside increase the fault level headroom, offers additional benefits of thermal headroom uplift, technical losses reduction and improves operational flexibility.

Total scheme cost £5.962m (2020/21 prices) represents most efficient solution to resolve the fault level exceedances in the groups and facilitate operating the group in intact condition. The proposed uprating scheme will create additional fault level headroom of 100MVA and provide and additional infeed of 7.5/10MVA in each group by the end of completion in 2028.

8 Appendices

8.1 Bentinck Street / Chester Street & MDHB Egerton Dock groups

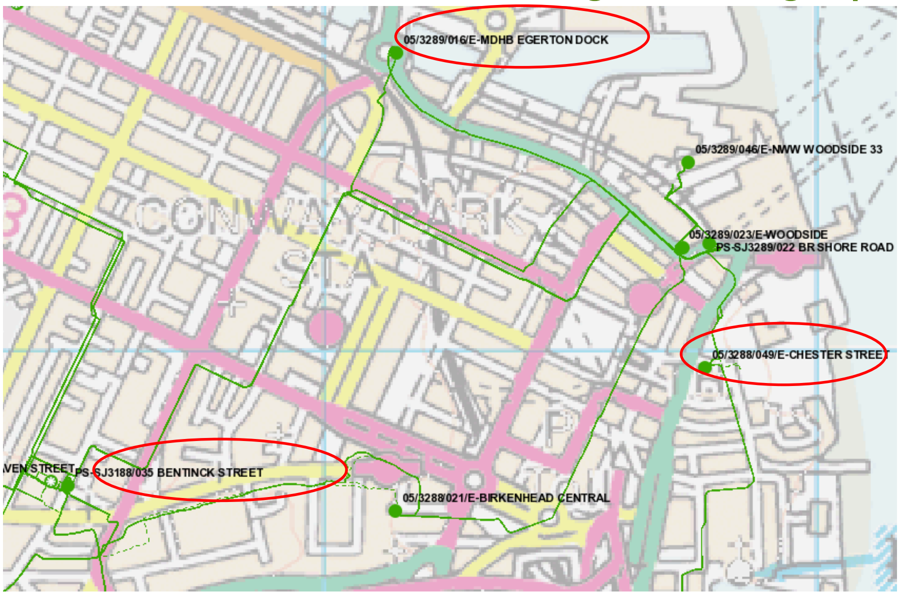


Figure 8-1: Bentinck Street / Chester Street & MDHB Egerton Dock site locations

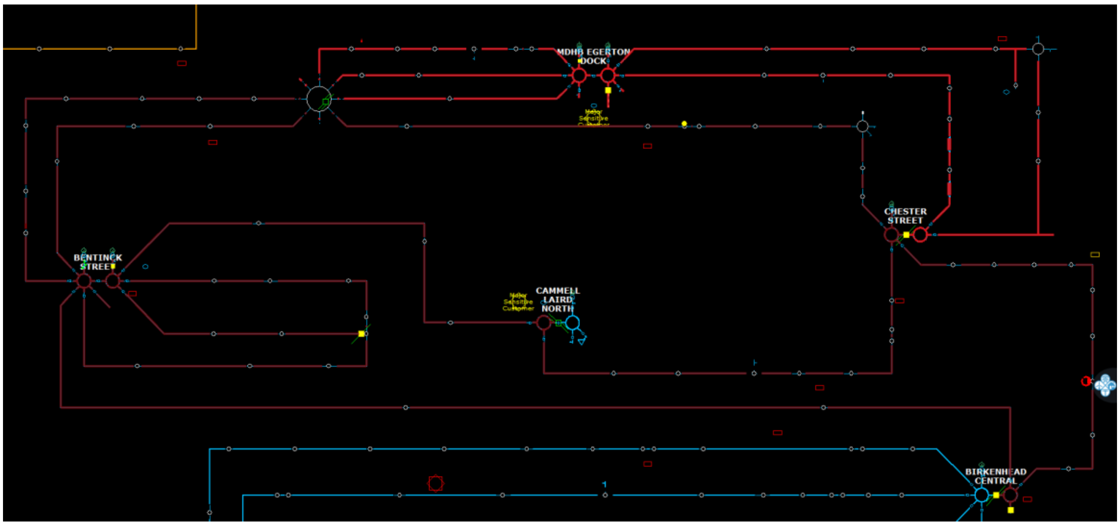


Figure 8-2: Bentinck Street / Chester Street & MDHB Egerton Dock operational diagram

Table 8-1: Option -1 Cost and volume breakdown (£m in 2020/21 Prices)

HV Group	**Primary Substation**	**Description**	**Volumes**	**Prime Costs (£m)**
Bentick St / Chester St	Bentinck Street	33kV Transformer (GM)	2	0.629
		6.6/11kV CB(GM) Primary	11	0.211
		Civil Works	-	0.120
	Chester Street	33kV Transformer (GM)	1	0.314
		6.6/11kV CB(GM) Primary	-	-
		Civil Works	-	0.060
		6.6/11kV Transformer (GM)	28	0.406
		6.6/11kV VT	6	0.030
MDHB Egerton Dock	MHDB Egerton Dock	33kV Transformer (GM)	2	0.629
		6.6/11kV CB(GM) Primary	11	0.211
		Civil Works	-	0.120
		6.6/11kV Transformer (GM)	12	0.174
		6.6/11kV VT	10	0.050
			Total Cost (£m)	**2.954**

Table 8-2: Cost incidence over the RIIO-ED2 period, £m (2020/21 Prices)

HV Group	**Total**	**Incidence (£m)**				
	(£m)	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Bentick St / Chester St & MDHB Egerton Dock	2.954	-	-	0.886	1.182	0.886

8.2 British Sidac / Sherdley Road / St Helens Linkway / Watery Lane

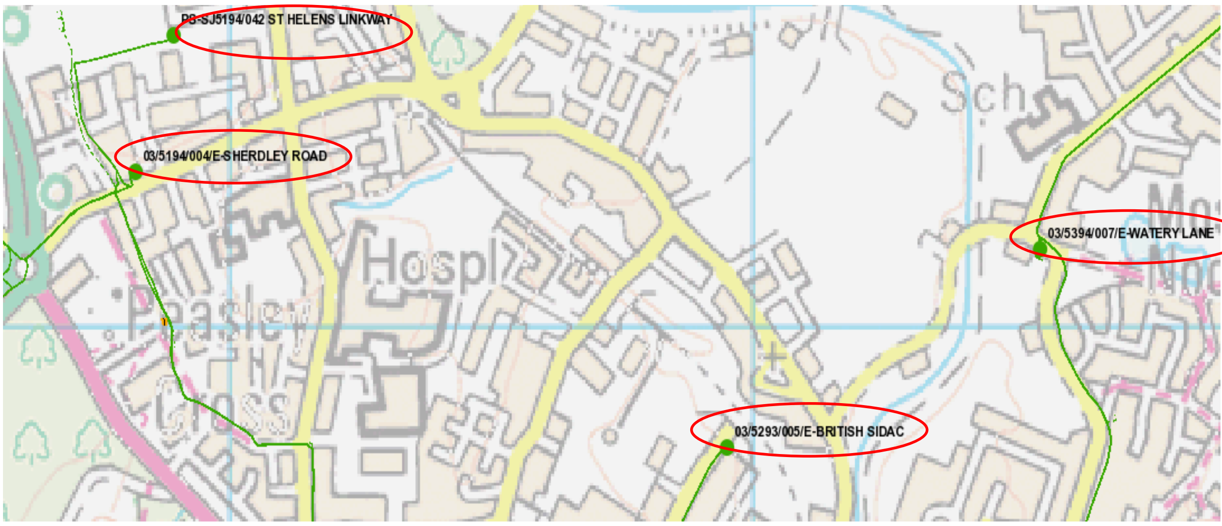


Figure 8-3: British Sidac / Sherdley Road / St Helens Linkway / Watery Lane site locations

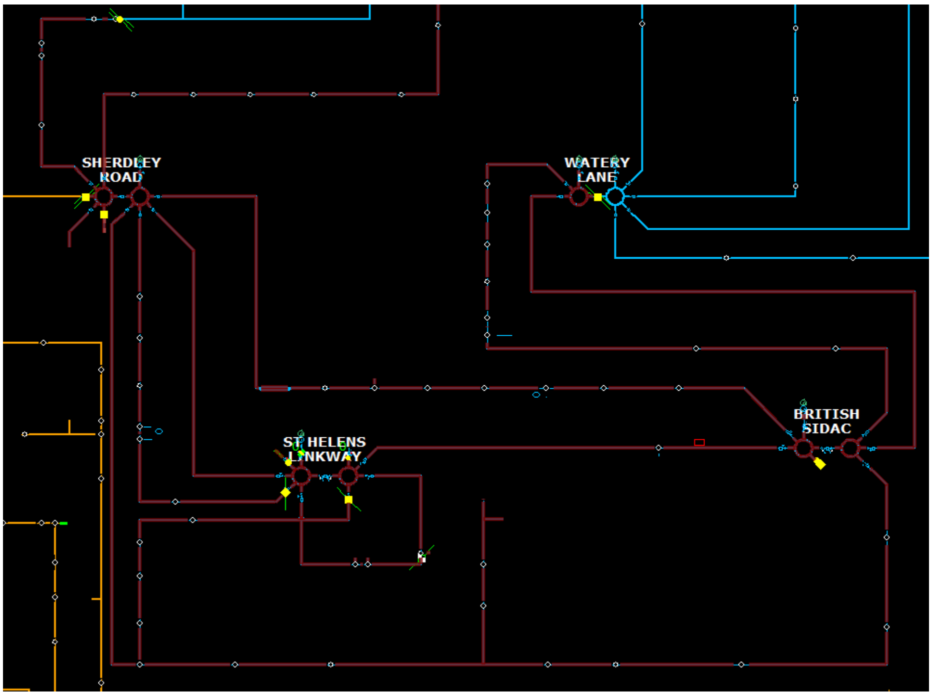


Figure 8-4: British Sidac / Sherdley Road / St Helens Linkway / Watery Lane site operational diagram

Table 8-3: Option -1 Cost and volume breakdown (£m in 2020/21 Prices)

HV Group	Primary Substation	Description	Volumes	Prime Costs (£m)
British Sidac / Sherdley Road / St Helen's Linkway / Watery Lane	British Sidac	33kV Transformer (GM)	-	-
		6.6/11kV CB(GM) Primary	-	-
		Civil Works	-	-
	Sherdley Road	33kV Transformer (GM)	1	0.314
		6.6/11kV CB(GM) Primary	11	0.159
		Civil Works	-	0.060
	St Helen's Linkway	33kV Transformer (GM)	-	-
		6.6/11kV CB(GM) Primary	-	-
		Civil Works	-	-

	Watery Lane	33kV Transformer (GM)	2	0.629
		6.6/11kV CB(GM) Primary	-	-
		Civil Works	-	0.120
		6.6/11kV Transformer (GM)	19	0.275
		6.6/11kV Transformer (PM)	2	0.012
		6.6/11kV VT	14	0.070
			Total Cost (£m)	**1.640**

Table 8-4: Cost incidence over the RIIO-ED2 period, £m (2020/21 Prices)

HV Group	**Total**	**Incidence (£m)**				
	(£m)	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**
British Sidac / Sherdley Road / S Helen's Linkway /Watery Lane	1.640	0.328	0.984	0.328	-	-

8.3 Gilbrook Dock / Hill Road / Mobil oil (Wallasey)

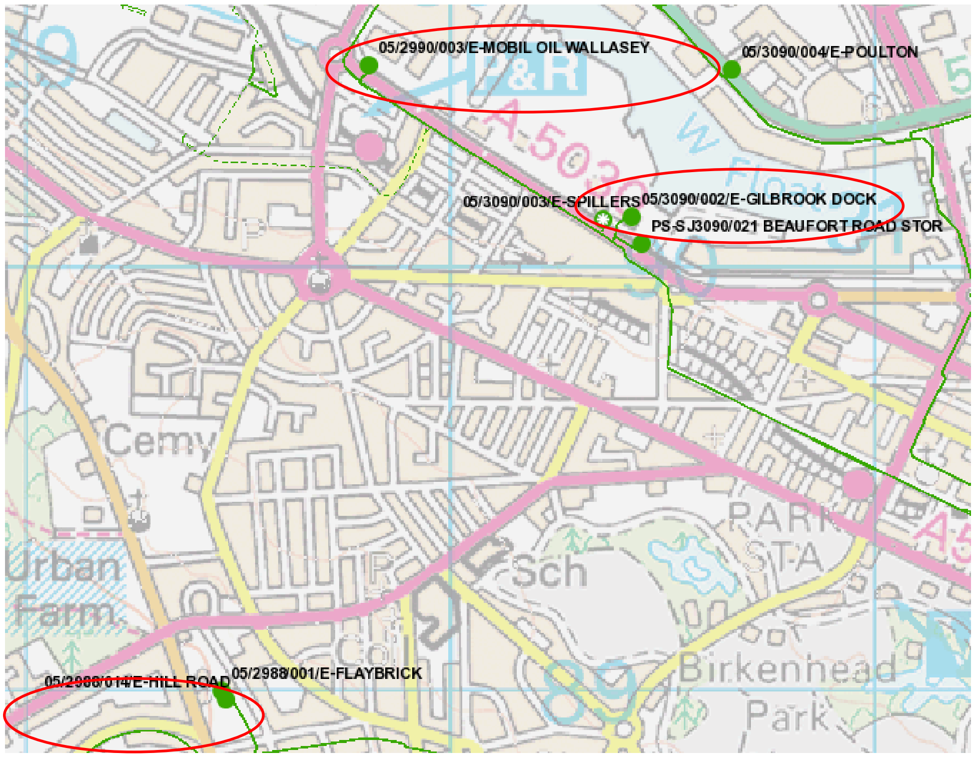


Figure 8-5: Gilbrook Dock / Hill Road / Mobil oil (Wallasey) site locations

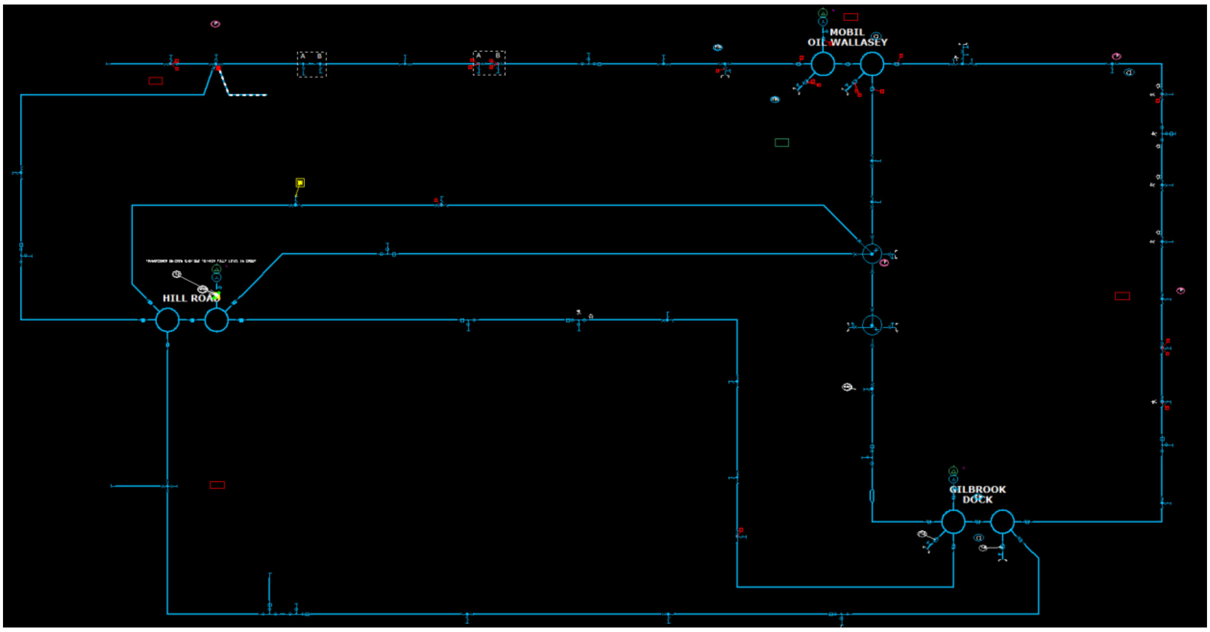


Figure 8-6: Gilbrook Dock / Hill Road / Mobil oil (Wallasey) operational diagram

Table 8-5: Option -1 Cost and volume breakdown (£m in 2020/21 Prices)

HV Group	Primary Substation	Description	Volumes	Prime Costs (£m)
Gillbrook Dock / Hill Road / Mobil Oil (Wallasey)	Gilbrook Dock	33kV Transformer (GM)	1	0.314
		6.6/11kV CB(GM) Primary	8	0.153
		Civil Works	-	0.060
	Hill Road	33kV Transformer (GM)	1	0.314
		6.6/11kV CB(GM) Primary	-	-
		Civil Works	-	0.060
	Mobil Oil (Wallasey)	33kV Transformer (GM)	-	-
		6.6/11kV CB(GM) Primary	-	-
		Civil Works	-	-
		6.6/11kV Transformer (GM)	28	0.406
		6.6/11kV VT	12	0.060
			Total Cost (£m)	**1.368**

Table 8-6: Cost incidence over the RIIO-ED2 period, £m (2020/21 Prices)

HV Group	Total (£m)	Incidence (£m)				
		2023/24	**2024/25**	**2025/26**	**2026/27**	**2027/28**
Gillbrook Dock / Hill Road / Mobil Oil (Wallasey)	**1.368**	0.684	0.410	0.274	-	-

8.4 Secondary (HV) substation types

Table 8-7: HV Substation types in each circuit

HV Group	Circuit ID	Total HV Substations (#)	Y-Type Substations (#)	X-Type Substations (#)	Y -Type Proportion (%)
Gillbrook Dock / Hill Road / Mobil Oil (Wallasey)	MW51602	9	-	9	0%
	MW51601	10	-	10	0%
	MW51604	6	-	6	0%
	MW51603	5	-	5	0%
	MW52802	11	4	7	36%

Bentick St / Chester St & MDHB Egerton Dock	MW52401	8	4	4	50%
	MW52402	6	1	5	17%
	MW52403	9	2	7	22%
	MW52405	18	2	16	11%
	MW52501	1	1	-	100%
	MW52504	7	1	6	14%
	MW52505	2	2	-	100%
	MW52507	7	-	7	0%
	MW55004	10	3	7	30%
British Sidac / Sherdley Road / S Helen's Linkway /Watery Lane	MW31301	6	6	-	100%
	MW31302	5	5	-	100%
	MW31304	3	3	-	100%
	MW31307	6	6	-	100%
	MW31308	14	14	-	100%
	MW31310	1	1	-	100%
	MW31803	8	5	3	62%
	MW32802	16	16	-	100%
	MW32803	4	4	-	100%