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<tr><td>Name of Scheme/Programme</td><td colspan="4">Charlotte Street New SGT1</td></tr>
<tr><td>Primary Investment Driver</td><td colspan="4">SQSS Compliance</td></tr>
<tr><td>Scheme reference/ mechanism or category</td><td colspan="4">SPT20066/7/8</td></tr>
<tr><td>Output references/type</td><td colspan="4">LRT2SP2027</td></tr>
<tr><td>Cost</td><td colspan="4">£4.357</td></tr>
<tr><td>Delivery Year</td><td colspan="4">2021</td></tr>
<tr><td>Reporting Table</td><td colspan="4">B0.7 Load Master Data
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<tr><td>Outputs included in RIIO T1 Business Plan</td><td colspan="4">No</td></tr>
<tr><td rowspan="2">Spend apportionment</td><td>Scheme</td><td>T1</td><td>T2</td><td>T3</td></tr>
<tr><td>SPT20066/7/8</td><td>£2.508m</td><td>£1.849m</td><td>£0m</td></tr>
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Issue Date	Issue No	Amendment Details
August 2020	Issue 1	First issue of document
-	-	-

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1 Introduction

SP Distribution has identified a fault level issue on their Charlotte Street 33 kV switchboards and has indicated that a SP Transmission solution is required to alleviate this problem. A Modification Application was submitted by SPD in February 2018, so that fault level mitigation works can progress.

Due to a type fault, SGT2 is currently programmed to be replaced in 2020 with a new 275/33 kV 120 MVA transformer with dual secondary windings (60+60 MVA). This design solution was approved to allow for additional fault level headroom to be established at this site in the future, following the replacement of SGT1 with a similar transformer. An interim running arrangement will be set up between the SGT2 and SGT1 works to ensure that the 33 kV fault level remains within the design level.

This paper proposes to change SGT1 with a new 275/33 kV 120 MVA transformer with dual LV windings (60+60 MVA) similar to SGT2. This will eliminate the existing fault level issue at Charlotte Street GSP and creates sufficient fault level headroom for future connections (approximately 25%).

2 Background Information

The progression of upgrade work at Charlotte Street GSP is shown in Figure 1. The replacement of SGT2 is currently underway and is planned to complete in 2020. At the end of that work, the network will be as shown in Figure 1 (b). This paper justifies the next stage of the Charlotte Street upgrade work which involves the replacement of SGT1 and the removal of the temporary arrangement shown in Figure 1 (b), to reach the final network configuration shown in Figure 1 (c).

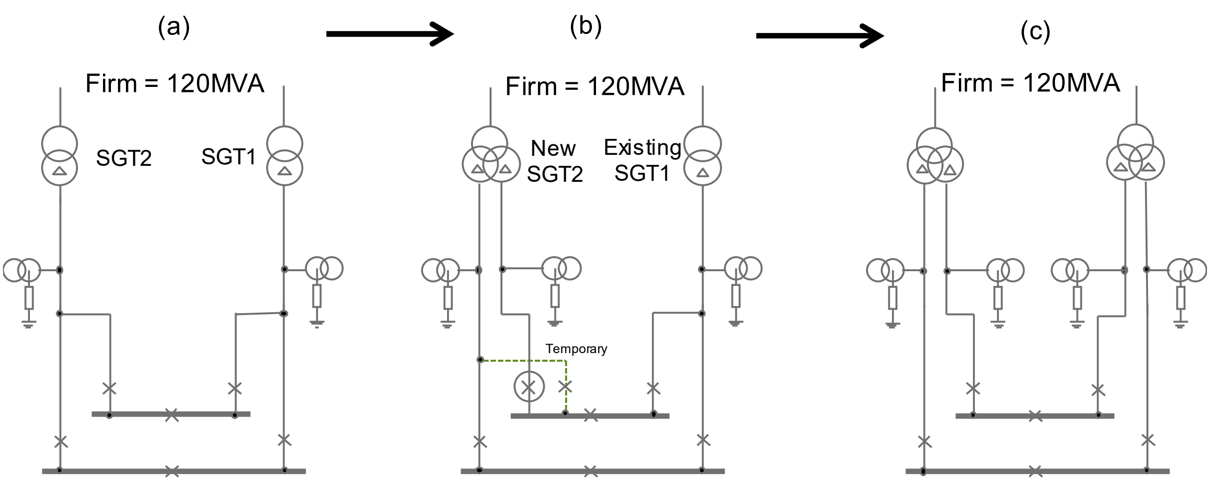

Figure 1. Charlotte Street 33kV transformer replacement.

The final network in Figure 1 (c) effectively splits the site into two 60 MVA 33 kV boards, retaining the total 120 MVA capacity while creating a significant amount of fault level headroom. This is the preferred long-term approach as a simple like-for-like replacement of the 120 MVA transformers would perpetuate the existing fault level problems. The fault level could be reduced by using very high-impedance transformers, but this would lead to an unacceptable reduction in power quality (i.e. non-compliance with voltage step requirements, poor voltage control and increased risk of flicker and/or voltage harmonic issues).

The interim running arrangement in Figure 1 (b) is required to ensure that the fault level at Charlotte Street 33 kV remains below the design fault level. While the two 33kV boards are coupled via the incoming circuits from SGT1, all three secondary windings would effectively be feeding one node, which leads to an excessive fault level. The temporary arrangement means that only one secondary winding of SGT2 is used to feed the 33kV bars, which would lead to overloading of SGT2 in the event that SGT1 is out of service. Therefore, an automatic scheme connects both SGT2 windings when SGT1 is disconnected. At maximum site demand, a single 60 MVA winding of SGT2 would be loaded to almost 140% and there is a risk of tripping the transformer and disconnecting all customers unless the automatic scheme connects the second winding rapidly. The interim solution is therefore not preferred. The analysis in Section 4 below also shows that the interim arrangement does not create sufficient fault level headroom to meet the project objectives.

The current peak demand at Charlotte Street is 81.6 MW, with the demand estimated to stay at a similar level over the next 5 years.

3 Optioneering

Table 1 provides a summary of the options considered for Charlotte Street 33kV.

Table 1: Longlist Proposed Options

	Option	Status	Reason for rejection
1	**No Intervention**	Rejected	It is not possible to undertake no intervention, as a modification application has been received from SPD specifically requesting a reduction in fault level infeed from the SP Transmission Network. This option would also not eliminate the temporary arrangement shown in Figure 1 (b), which limits the available fault level headroom.
2	**New 275/33 kV 120 MVA Dual LV Winding Transformer**	Proposed	-
3	**Enhanced Fault Level Assessment**	Rejected	Current network models are based on static assumptions about network conditions. Improved modelling of the network through data collection and real-time network operating conditions would allow for more accurate modelling. However, more detailed assessment has a small impact (the fault level is dominated by the SGT impedance) and does not reduce the fault level and therefore this option has been discounted. This option does not eliminate the temporary arrangement at the site.
4	**Transformer Auto-Changeover and Network Reconfiguration**	Rejected	Allows for high levels of fault level reduction but reduces the overall thermal capacity available at the site. It also leads to significant network disturbances and associated customer service issues, with temporary loss of supply during network reconfiguration.

5	**Bus Section Reactor 33kV**	Rejected	The installation of a bus section reactor is not viable at the GSP site due to the configuration of the GSP. The installation of a bus section reactor on this site would require 4 x 33 kV circuit breakers and a complex operational scheme to ensure the fault level is correctly mitigated (i.e. to avoid operational switching errors). As such this has not been taken forward as a short list solution in this case.
6	**SGT1 Series Reactor 33 kV 120 MVA**	Rejected	This solution effectively increases the impedance of SGT1. While this solution would reduce the fault level, it is incompatible with the overall design philosophy for the site. Further, this solution would lead to an unacceptable reduction in power quality, i.e. excessive voltage steps in the event of an SGT2 outage and poor voltage control. There is also an increased risk of flicker and/or voltage harmonic issues.
7	**SGT1 Series Reactor 275 kV 120 MVA**	Rejected	See the discussion for option 6 above. The installation of a series reactor on the 275 kV side of the transformer would increase the total impedance, but the higher voltage rating would lead to increased costs for the associated reactor and as such has been discounted from the short list of options.
8	**Resistive Superconducting Fault Current Limiter**	Rejected	A solid state device which under normal operating conditions provides minimal resistance but in the event of a fault, the conductor moves out of superconducting state and becomes a resistor. This device introduces complex operational and maintenance requirements with the introduction of cryogenic systems onto the network. These devices are also very costly when compared to other options, both in capital costs to install and also operational costs to maintain.
9	**Pre-Saturated Core Fault Current Limiter**	Rejected	This device limits fault current during a fault. This system is only available from one supplier and would introduce complicated operational and maintenance requirements into the business and as such it has not been taken forward as a short list option.
10	**I_s-Limiter**	Rejected	The use of this technology, which relies on an explosive charge, would introduce complex operational and maintenance requirements onto the network. As such this has not been taken forward to the short list selection.
11	**Increase system fault level limit**	Rejected	Installing higher rated switchgear could allow for increased fault level capacity allowing for additional generation to connect to the network. This however has implications on other plant and equipment connecting and connected to the network and on existing EHV customers. We would also require reviewing the capability of other plant and apparatus to withstand the higher fault level. As such this has not been taken forward as a proposed solution.

Of the longlist options considered, only Option 2 (replacing SGT1 with a new 60+60 MVA dual-secondary transformer) is feasible.

4 Detailed Analysis

The results of fault calculations for different network arrangements at Charlotte Street 33 kV are shown in Table 2. The results show that the original network with two single-secondary 120 MVA transformers as shown in Figure 1 (a), exceeds the design fault level unless operational measures are put in place. Such measures would reduce the demand security at the site and also limit operational flexibility in the 33 kV network. The fault level remains excessive after the replacement of SGT2, unless the temporary arrangement shown in Figure 1 (b) is used to limit the fault level. This temporary arrangement reduces the fault level to within the design level, but does not create sufficient fault level headroom (the peak make current remains close to the maximum level).

Table 2. Fault levels

Network Configuration	**Peak Make (i_p)**		**RMS break (I_b)**		**Peak Break (i_b)**	
	kA	**% of Rating**	**kA**	**% of Rating**	**kA**	**% of Rating**
Old arrangement Figure 1 (a)[1]	55.85	125%	19.48	112%	38.06	90%
Without interim switching arrangement in Figure 1 (b)	57.44	129%	20.77	119%	39.35	93%
Temporary arrangement Figure 1 (b)	44.11	99%	15.76	90%	30.46	72%
Final system Figure 1 (c) 33 kV Board A	32.67	73%	11.93	68%	22.35	53%
Final system Figure 1 (c) 33 kV Board B	33.49	75%	12.24	70%	22.55	54%

The fault levels at Charlotte Street 33 kV will increase with the connection of Strathclyde University CHP, which is contracted to connect. In addition, other applications for connection to this site are being delayed or diverted to other sites like West George Street or Dalmarnock where connections are less efficient due to longer cable routes, etc. A connected generator site at Polmadie has already been diverted to Dalmarnock from Charlotte Street due to fault level constraints. Further increases in smaller embedded generation schemes are also expected. Table 3 shows the increases in embedded generation capacity by scenario, all of which will lead to increases in fault level. Note that the Steady Progression generation capacity of 9.9MW has already been exceeded by generation projects under construction and those contracted to connect.

Table 3. Embedded generation at Charlotte Street 33kV

Scenario (FES 2019)	**Embedded Generation Capacity (MW)**	
	2018	**2040**
Community Renewables	0.96	54.2
Two Degrees	0.96	37.2
Steady Progression	0.96	9.9
Consumer Evolution	0.96	43.6

By replacing SGT1 with a dual-secondary (60+60 MVA) transformer identical to the new SGT2, the proposed solution for this project, significant additional fault level headroom is created as shown in Table 2 (note that fault levels for both 33 kV boards are given). This reduces the fault level to

[1] Based on ETYS 2018 results and does not reflect the impact of all embedded generation expected to connect.

around 75% of the design level, creating headroom for contracted and expected future generation connections.

5 Future Pathways – Net Zero

Primary Economic Driver

The primary driver for this investment is to reduce the fault level at Charlotte Street 33 kV to within design limits and to provide additional headroom for the connection of embedded generation.

Payback Periods

A payback period has not been considered.

Pathways and End Points

There is a high level of connection application activity at this site. The investment to reduce the fault level at Charlotte Street provides headroom for the connection of new embedded generation in the area.

Asset Stranding Risks

There is no asset stranding risk associated with this funding.

Sensitivity to Carbon Prices

We have not tested this sensitivity for this project.

Future Asset Utilisation

We expect utilisation of the assets to continue to increase as future demand and generation connected to the site increase.

Whole Systems Benefits

The solution proposed is a transmission solution to a distribution issue. Both transmission and distribution solutions have been evaluated in cooperation with SPD. A whole-system approach has been taken to identify the most economic and efficient solution while also taking changes for Net Zero into account.

6 Conclusion

Eleven long-list options have been reviewed in terms of scope, costs, timescales, construction risk and feasibility. Only one option, replacement of SGT1 with a new 60+60 MVA dual-secondary transformer, is considered feasible for this project and is recommended to proceed.

This option creates sufficient fault level headroom at the site and ensures that the full 120 MVA firm capacity of the GSP will be available to demand and generation, noting that this depends on the fault infeed characteristics of the connected generation.

Project Summary:

- Forecast Costs – £4.357m
  - SPT funded – £0.071m
  - SPD funded – £4.286m
- Timing of Investment – 2022
- Outputs:
  - Addition – 1 x 275/33 kV 120 MVA (60+60 MVA) dual-LV transformer
  - Disposal – 1 x 275/33 kV 120 MVA single-LV transformer

7 Outputs included in RIIO T1 Plans

No outputs are included in RIIO-T1 plans.