Proposed Expansion Constant and Expansion Factor calculations for CMP 375

CMP 375 Workgroup

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This report outlines the approach developed by LCP to calculate revised expansion factors for use in the calculation of Transmission Network Use of System (TNUoS) charges.

Background

The Workgroup for CMP 375 has been considering amendments to the calculation of the Expansion Constant and Expansion Factors to better reflect the growth of and investment in the National Electricity Transmission System (NETS).

Current approach

The current TNUoS charge calculation methodology uses an expansion constant value which is designed to reflect the cost of building a new 400kV overhead line (OHL). This is measured as a cost per MW-km, assuming the overall cost scales both with the rating of the asset and the length of the asset.

To reflect the diversity of the transmission network, expansion factors are applied as multipliers if the reinforcement is required at a different voltage level or on another type of circuit.

The only other factor used to calculate the cost of reinforcements is the locational security factor. We have not considered this as it is outside the scope of CMP 375.

The table below shows the expansion constant and expansion factors use for calculating the 2021/22 TNUoS charges.

Parameters used for final 2021/22 TNUoS charges

Expansion constant	15.0507	£/MW-km

		Pure GB	TO Specific		
Voltage (kV)	Link Type		NGC	SP	SSE
400	OHL	1.00	1.00	1.00	1.00
275	OHL	1.20	1.20	1.20	1.20
132	OHL	2.87	2.87	2.87	2.59
400	Cable	10.20	10.20	10.20	10.20
275	Cable	11.45	11.45	11.45	11.45
132	Cable	22.58	22.58	22.58	20.77

Issues with the current approach

The TNUoS charge calculation methodology assumes that the transmission network is at capacity with the current generation fleet, and that any additional load would lead to additional reinforcement. In practice, the network has spare capacity in some areas so new circuits are not always required.

Combined with this, another underlying assumption is that all reinforcements on the transmission network are new circuit build. This approach ignores other reinforcements which add network capacity and those which are required to avoid network capacity decreasing.

In practice, there are few new circuits and most reinforcement comes from asset replacement or refurbishment. This has led to another issue: that there is very little data to use to calculate the expansion constant and factors under the current methodology.

Proposed new approach

The Workgroup has suggested expanding the methodology to include other reinforcements alongside new circuit build. The expanded methodology would include:

a) New circuit build

b) Circuit replacement/refurbishment

c) New non-circuit build e.g. substations

d) Non-circuit reinforcement e.g. transformers

e) 'Smart' reinforcement option e.g. intertrips and ANM

f) Life extension options

g) Non-thermal solution options e.g. circuit breaker replacement

Due to the availability of data, this report focuses on an approach which includes the first four types of network reinforcement (a-d).

The new approach will calculate a new expansion factor for each voltage level and circuit type based on the average cost of the reinforcements implemented.

If there is a requirement for significant new circuit build, then the methodology will produce similar expansion factors to current values. However, if most reinforcement involves circuit replacement rather than new build, then the expansion factor values could be lower.

Required data for each reinforcement type

For each reinforcement type, the following data is required:

- **Cost of the reinforcement.**

  This should vary by voltage level and could also vary by transmission operator region if data is available.

- **Additional network capacity provided** by the reinforcement, measured in MW-km.

  For many reinforcements, such as circuit replacement, this value will be simple to calculate given the rating and length of the asset. A separate methodology is required for assets where there is not a clear measure of the network capacity added, such as replacing transformers.

- **Expected number of reinforcements** of each type over a fixed period.

  This could be split by transmission operator if data is available. The benefit of this is that expansion factors for different regions will be more appropriate for the reinforcements required in those regions. However, if data is limited then the reduced sample size could make splitting less appropriate.

Methodology outputs

The output of the methodology will be an expansion factor value for each type of reinforcement for which there is data. There will also be an average expansion factor value by circuit type and voltage level for each TO region.

These expansion factors can then be used in the current NGESO Transport Model, replacing the current values, and new charges can be calculated.

Data collected

LCP conducted a review of available data on each of the reinforcement types, looking through data published by transmission operators in GB about the costs of their reinforcements and the reinforcement they plan to make.

The data we have used so far has come from Scottish Power's (SP) annexes to their RIIO-ET2 business plan which can be found here:

https://www.spenergynetworks.co.uk/pages/riio_t2_business_plan_annexes.aspx

The key annexes are:

- RIIO-ET2 Business Plan Data Tables (Annex 11)

  This provides a breakdown of the reinforcements planned for the price control and the assets currently in place on their network.

- RIIO-ET2 Engineering justification papers (Annex 1)

  These provide cost estimates for and descriptions of key reinforcements that are planned for the price control.

For the other two transmission operators (National Grid and Scottish Hydro Electric), some or all this data has been redacted in the published versions of the RIIO-ET2 business plan. The analysis would be significantly strengthened, and regional variations could be accounted for if this data were available.

Additionally, three other data sources have been used in this analysis:

- Electricity Transmission Costing Study report produced by Parsons Brinckerhoff in 2012

  This has been used to estimate the cost of new build 400kV cables and OHL.

  https://www.stjornarradid.is/media/atvinnuvegaraduneyti-media/media/fylgigogn-raflinur-i-jord/9-transmission-report.pdf

- WPD's RIIO-ED2 business plan (table 11)

  This is used to estimate the proportion of the costs reported in the engineering justification papers that are attributable to the expansion constant and expansion factors.

  https://yourpowerfuture.westernpower.co.uk/downloads/42114

- National Grid ESO's Transport Model for final 2021/22 TNUoS tariffs

  This has been used to provide some circuit information where it was not detailed in engineering justification papers, and for some average properties of transformers.

Data processing

In this section, we explain how the data for reinforcement costs and the number of expected reinforcements has been processed.

Extracting reinforcement costs

Each of the engineering justification papers relates to a specific reinforcement that is planned for RIIO-ET2. For example, the image below shows an extract for refurbishment of a 400kV OHL asset on SP's network.

Example 400kV refurbishment

ZA ROUTE 400kV OHL MAJOR REFURBISHMENT	
Name of Scheme/Programme	ZA Route 400kV OHL Major Refurbishment
Primary Investment Driver	Asset Health
Scheme reference/ mechanism or category	SPNLT205/Overhead (Tower) Line
Output references/type	NLRT2SP205/400kV OHL (Tower) Conductor, NLRT2SP205/400kV Fittings, NLRT2SP205/400kV OHL Tower
Cost	£44.6M
Delivery Year	2023
Reporting Table	C0.7/C2.2a_AP/C2.2a_CI/C2.3/C2.4b/C2.5/C2.5a
Outputs included in RIIO T1 Business Plan	No

Asset	**Type of Activity**	**Disposal (cct. Km/sets/each)**	**Addition/Activity (cct. Km/set/each)**
400kV OHL (Tower Line) Conductor	Replacement	131.6 cct. Km	131.6 cct. Km
400kV OHL Fittings	Replacement	388 sets	388 sets
400kV Tower	Refurbishment Major	-	194 each

For this reinforcement, there are three types of assets being refurbished or replaced: the conductor, the fittings, and the towers. Where all the assets affected are directly related to a specific type of reinforcement as in this case, we have not adjusted the cost estimate.

In some cases, multiple reinforcement types are included in the same justification paper. For example, circuit refurbishment at multiple voltage levels. As their costs are not reported separately and these are relatively rare, we have excluded these from our analysis.

Data exclusions

Some of the individual reinforcements have been excluded from the analysis where they either produce values which are clear outliers or where their properties are significantly different from others. There are very few exclusions of this nature. Examples include excluding circuit reinforcements where the length of circuit is low (below 5km).

Inflation

We have assumed that each of the cost values given in the engineering justification papers are 2018 costs as this is when they were published. The cost values from Parsons Brinckerhoff are assumed to be from 2012 when the paper was published. In our analysis, all costs are inflated to £2021.

Removing costs not applicable to expansion factors

Not all the costs of reinforcements should be included in the expansion constant calculation. Examples of excluded costs include consents, diversions and land. The costs should instead relate specifically to the costs of the assets and their installation.

We have assumed that the costs given in the engineering justification papers include all costs related to those reinforcements. However, no breakdown is given to extract the relevant costs.

The most applicable data we have found comes from Western Power Distribution's RIIO-ED2 business plan, where total costs for the price control are broken down into each area. The table containing this data is shown below:

WPD's proposed expenditure breakdown under RIIO-ED2

WPD Total Expenditure								
£m at 2020/21 prices	Average per year in RIIO-ED1	Average per year in RIIO-ED2	Spend profile in RIIO ED2					Total RIIO-ED2
			2023/24	2024/25	2025/26	2026/27	2027/28	
Connections requiring reinforcement	25	47	41	45	48	54	47	235
Primary reinforcement	33	52	76	42	56	54	33	261
Secondary reinforcement	28	75	56	68	83	81	86	374
Fault level reinforcement	6	12	18	16	16	5	4	59
New transmission capacity charges	0	3	1	2	2	3	10	17
Reinforcement of the network	**91**	**189**	**193**	**171**	**206**	**197**	**180**	**946**
Diversions	39	49	49	50	49	48	48	244
Diversions (rail electrification)	2	0	0	0	0	0	0	0
Asset Replacement and refurbishment	222	256	240	252	268	250	268	1,279
Civil works driven by condition of civil items	15	14	14	14	14	14	14	69
Black Start	4	0	0	0	0	0	0	0
Legal and Safety	5	9	8	9	9	10	9	45
Quality of supply	6	5	5	5	5	5	5	25
Flood mitigation	1	2	2	3	3	2	2	12
Physical security	0	0	0	0	0	0	0	0
Rising and lateral mains	0	0	0	0	0	0	0	2
Overhead line clearances	18	24	25	25	28	24	20	122
Worst served customers	1	1	1	1	1	1	1	4
Visual amenity and undergrounding in National Parks and Areas of Natural Beauty	1	1	1	1	1	1	1	7
Losses	1	1	1	1	1	1	1	5
Environmental activities	4	6	9	9	8	1	1	29
Non Load network investment	**320**	**368**	**356**	**370**	**388**	**358**	**371**	**1,842**

The costs that are relevant to the expansion constant and expansion factors are 'Reinforcement of the network' and 'Asset replacement and refurbishment'. These represent approximately 79.8% of total network investment.

We have assumed that the same percentage applies to all reinforcements at the transmission level.

There are limitations to using this data as it applies to distribution networks and the appropriate percentage to apply may vary significantly between different types of reinforcements. However, the WPD data implies that we should make some adjustment for these excluded costs as they could be material.

Additional calculations for non-circuit reinforcements

Methodology

For non-circuit reinforcements, it is challenging to estimate the reinforcement provided in terms of circuit capacity in MW-km.

We have chosen to interpret this in terms of the circuit capacity that these non-circuit assets enable, or that would be lost if the asset were not replaced.

Using the National Grid ESO Transport Model, we have calculated the average MW-km of circuit capacity that is connected at a typical substation at different voltage levels.

Below is a table of the average number of circuit assets connected to each substation and the average total MW-km values for those assets.

Typical substation circuit connections in NGESO's Transport Model

Voltage level	# lines connected	MVA-km connected
400	10.53	257,301
275	13.39	118,664
132	11.33	10,480

This provides a proxy for the circuit capacity enabled by the non-circuit assets located at a substation, such as transformers or circuit breakers.

However, using this value directly risks double counting the capacity added by the full set of reinforcements. For example, some of these circuits will need to be reinforced themselves within the next price control so the transformer should not be considered to have enabled these assets.

To avoid double counting, we have calculated the proportion of circuit assets at each voltage level which are scheduled for refurbishment within the next price control. This has been calculated using SP's Business Plan Data Tables for RIIO-ET2. We have also calculated the proportion of transformers and circuit breakers scheduled for replacement.

The circuit capacity a non-circuit asset is considered to enable is scaled down to match the proportion of circuit assets that are not scheduled for refurbishment in the next price control either through direct refurbishment or replacement of other non-circuit assets. For example, the reinforcement provided by a new transformer accounts for the capacity already added by direct circuit replacement and any circuit breaker replacement.

Illustratively, if 40% of the circuit capacity at 400kV is assumed to be refurbished in the price control and 10% of circuit breakers are due for replacement, then the value of the capacity enabled by a transformer at that voltage level is scaled down by (100% - 40%) * (100 % - 10%) = 54%.

The overall effect of this approach is that if more other circuit and non-circuit reinforcements are required, then the contribution of any single non-circuit reinforcement decreases as expected.

Limitations

A key limitation of this approach is that the value it is trying to calculate is not well-defined and is open to interpretation. This approach assumes that the circuit capacity provided is equal to the circuit capacity that is enabled and not otherwise reinforced in the next price control. However, this aligns with the rationale for including circuit replacement in the reinforcement cost calculation – that preventing existing capacity from leaving the network is equivalent to adding new circuit assets.

The analysis could be updated to consider a different timeframe for other reinforcements rather than the next price control. In the extreme case, all assets need replacement eventually, so non-circuit assets could be viewed as adding no capacity. This analysis is sensitive to the timeframe assumed.

This approach has inconsistences with how we view circuit reinforcement or new build. We do not reduce the added capacity of circuit assets if non-circuit assets which enable them would need replacement.

The network capacity added by non-circuit assets is sensitive to their location, but we make no adjustments for the specific network topology around those assets.

Average reinforcement cost calculation from underlying data

OHL and Cable new build cost

The Parsons Brinckerhoff dataset provides costs for new build OHL and Cable at 400kV. No data is provided at 275kV or 132kV.

In the later analysis, we use the existing expansion factors for these voltage levels as these should be applicable for these reinforcements.

OHL and Cable replacement/refurbishment cost

For these reinforcements, we have taken a volume weighted average cost per MW-km of the included reinforcements.

There were no examples of replacement or refurbishment of cables at 275kV or 400kV and only one of these reinforcements for 275kV OHL.

Transformer and circuit breaker replacement cost

For these reinforcements, we have taken an average of the cost of the included reinforcements.

The reinforcement cost is similar across voltage levels. However, these values are divided by the assumed circuit capacity provided in MW-km. This capacity is larger for higher voltage levels, resulting in lower reinforcement costs per MW-km.

Missing expansion factor values

For new build circuits at 275kV and 132kV, we do not have values for the cost of reinforcement. We have chosen to use the existing expansion factor values for these reinforcements.

For cable replacement at 275kV and 400kV we do not have any reinforcements in our data set. We have assumed that the cost of these relative to a 132kV reinforcement is the same as it is for new build circuit reinforcements.

The table below summarises the quantity of data available for each reinforcement type.

Voltage	New build OHL	New build cable	OHL replacement	Cable replacement	Transformer replacement	Circuit breaker replacement
400kV	P-B data	P-B data	2 assets	No data	1 asset	2 assets
275kV	No data	No data	1 asset	No data	2 assets	1 asset
132kV	No data	No data	4 assets	2 assets	1 asset	3 assets

Coloured cells indicate level of confidence given the quantity of data available.

- The key area of concern is the small data set for circuit replacement at most voltage levels
- Though there are limited numbers of assets for non-circuit assets, the raw reinforcement cost is very similar across voltage levels.
- The Parsons Brinckerhoff study is based on surveys of over 100 suppliers and manufacturers so in itself represents a good sample size.

The analysis would be significantly strengthened by additional data from other transmission operators.

Expansion constant and factor calculations

Expansion factors by type of reinforcement

Expansion factors represent the cost of adding network capacity at a given voltage level on a type of circuit relative to the cost of building a new 400kV OHL. When calculating new expansion factors, we have maintained this definition.

The table below shows the expansion factors calculated for each type of reinforcement by voltage level. Coloured cells indicate where data was unavailable, and the methods described in the previous section were applied.

Voltage	New build OHL	New build cable	OHL replacement	Cable replacement	Transformer replacement	Circuit breaker replacement
400kV	1.00	10.88	0.54	6.74	0.12	0.05
275kV	1.20	11.45	1.65	7.10	0.15	0.07
132kV	2.87	22.58	3.12	13.99	1.43	0.66

Some of the key findings from this calculation are:

- As expected, the cost of circuit replacement can be lower than the cost of new build circuits
- Where there is limited data available, some circuit replacement is more expensive than new circuits. With more data available, it would be possible to check that these results are not driven by a few expensive reinforcements.
- Non-circuit assets are calculated as low-cost reinforcements at all voltage levels. The cost is higher at lower voltage levels as with other reinforcements.

Calculating average expansion factors

The current methodology uses a single expansion factor for each voltage level and type of circuit. We have maintained this approach for simplicity and because introducing specific reinforcements into the NGESO Transport Model calculation would be prohibitively difficult.

For each voltage level and type of circuit, the new approach has multiple methods of reinforcement alongside building new circuits. The expansion factor has been calculated to represent the average cost of adding network capacity given the types of reinforcements that are expected.

The reinforcements that we expect to be implemented are taken from SP's Business Plan Data Tables, where they set out the volume of reinforcements of each type that are expected in the upcoming price control.

Notably, this involves high levels of circuit replacement and new non-circuit assets, and very few new circuits. This means that the resulting expansion factor will be driven more by circuit replacement and non-circuit reinforcement than by new circuit build.

The table below shows the reinforcements planned by SP in the upcoming price control.

SP circuit and non-circuit reinforcements in RIIO-ET2 business plan

Voltage Units	New build OHL km	New build cable km	OHL replacement km	Cable replacement km	Transformer replacement #	Circuit breaker replacement #
400kV	0	0	548	0	4	15
275kV	0	0	204	13	18	39
132kV	0	8	280	41	10	28

Note that for non-circuit assets, it is not clear which type of circuit assets they should be included as for the calculation of the expansion factors. We have chosen to include the same percentage of reinforcement cost in both circuit types.

Expansion factor scenarios

Due to the increased uncertainty around the reinforcement provided by non-circuit assets, we have provided expansion factors under two scenarios:

- Option 1: include non-circuit assets in the calculation
- Option 2: exclude non-circuit assets from the calculation

Taking this approach allows us to look at Option 2 and understand the impact of accounting for circuit refurbishment and replacement in isolation.

The resulting expansion factors under these two scenarios are shown in the tables below:

Expansion factors under Option 1

Voltage	New approach - Option 1 OHL expansion factor	New approach - Option 1 Cable expansion factor	Current approach OHL expansion factor	Current approach Cable expansion factor
400kV	0.47	5.75	1.00	10.20
275kV	0.81	3.31	1.20	11.45
132kV	1.29	5.05	2.87	22.58

Expansion factors under Option 2

Voltage	New approach - Option 2 OHL expansion factor	New approach - Option 2 Cable expansion factor	Current approach OHL expansion factor	Current approach Cable expansion factor
400kV	0.54	6.74	1.00	10.20
275kV	1.65	7.10	1.20	11.45
132kV	3.09	14.94	2.87	22.58

The key findings from these results include:

- Under Option 1, the resulting expansion factors are lower than under the current approach.
- Under Option 1, the reinforcements at 400kV are more expensive than those at 275kV and 132kV. This is due to differences in the distribution of reinforcements expected at these voltage levels – there are more non-circuit reinforcements at the lower voltage levels.
- Under Option 2, some of the 275kV and 132kV expansion factors are higher than the current approach. As before, this is due to a small sample size of reinforcement costs for circuit refurbishment at these voltage levels.
- Under Option 2, the resulting expansion factors are higher than under Option 1 as the lower-cost non-circuit reinforcements are excluded.

Conclusion and next steps

The analysis outlined in this report puts forward a methodology for calculating expansion factors which:

- Includes different types of network reinforcements other than new circuit build
- Accounts for the quantity of each type of network reinforcements expected in the medium-term
- Can be expanded and improved with additional or higher quality data from transmission operators

In particular, the analysis found that making these changes could significantly reduce the expansion factors used in the NGESO Transport Model, resulting in a weaker locational signal in TNUoS charges.

The priority next step is to source additional data from Transmission Operators to fill gaps in the dataset and clarify if some of the unexpected results shown are due to data anomalies.

The other important follow-up step is to present this approach to the wider CMP375 workgroup and transmission operators for comment, challenge and review.

If the reader is interested, LCP have provided Ocean Winds with a supporting workbook containing the data used and showing the calculation used to implement this methodology.

Please do not hesitate to contact us if you have any questions about the contents of this report.

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