Armagh Upgrade

Preliminary Preferred Options Report

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Summary

A Needs Report has been prepared for reinforcing the transmission and distribution networks in Armagh and Drumnakelly. This has been prepared as a joint report by SONI and NIE Networks.

The Portadown, Craigavon and Armagh areas are supplied by Drumnakelly Main 110/33 kV bulk supply point (BSP) in Portadown. This substation currently has a demand just under 90 MVA, which is approaching the nominal rating of the 110/33 kV transformers. With uptake in low carbon technologies such as electric vehicles (EVs) and heat pumps this is expected to be exceeded. However, the site will remain compliant with the Transmission and Distribution System Security and Planning Standards (TSSPS and DSSPS) using the cyclic overload capability of the transformers (approx. 13.5% overload capacity in winter) up to 2032. Beyond 2032 post fault demand transfer to Waringstown Main may be required (taking advantage of duplicate 33 kV cable circuits rated 40 MVA each). However, this approach may require the automatic disconnection of load to prevent overload prior to the demand transfer and as the 33 kV system is operating radially during this time there could be further risk to supplies in the event of a second outage. This would not be sustainable long term as whilst meeting the minimum requirement it does involves additional risk to supplies, becomes more difficult operationally to manage and provides no capacity for future load growth.

Just under half of the load on Drumnakelly Main is taken by Armagh city and several surrounding towns and villages. This is supplied via four 33 kV overhead lines which operate in parallel. Under N-1 contingency on this 33 kV system during peak demand the statutory voltage requirements are not currently met and there is a risk of overload to the remaining in-service circuits.

Reinforcement is required to resolve the above thermal and voltage constraints.

This report has been prepared jointly by NIE Networks as Distribution Network Owner (DNO) and SONI. NIE Networks and SONI appraised a long list of options to address the project need as follows:

- Option 1 - Do nothing (**£0m**);
- Option 2 - Second Bulk Supply Point (BSP) at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and new Tullygoonigan - Richill 33 kV ring **(£23.90m);**

- Option 3 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and rebuild existing Tullygoonigan - Richill 33 kV circuit (£20.85m);
- Option 4 - Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits (£29.43m);
- Option 5 - Connection of a new Armagh Central BSP to Tandragee via one new monopole single 110 kV circuit (£13.81m);
- Option 6 - Connection of a new Armagh Central BSP to the proposed Turleenan 400/275 kV substation (£64.16m);
- Option 7 - Connection of a new Armagh Central BSP to the proposed Turleenan – Woodland 400 kV circuit (£99.08m); and
- Option 8 - Connection of a new Armagh Central BSP to Tandragee via two new underground cable 110 kV circuits (£64.04m).

To reduce the long list of options to a short list for more detailed assessment, each option was subject to appraisal of its capital cost, technical merits and deliverability.

For Option 1 – Do nothing, the demand at Drumnakelly Main is forecast to exceed the nominal 90 MVA rating of the 110/33 kV transformers. This can be managed in the medium term by initially using the cyclic overload rating of the transformers (estimated at a further 13.5% in winter) and beyond that implementing a 33 kV post fault demand transfer using the duplicate 40 MVA 33 kV circuits to Waringstown Main. It may require the automatic disconnection of load to prevent overload during the 33 kV transfer switching. Whilst meeting the minimum criteria of the TSSPS and DSSPS it does introduce added risk to supplies if for example there was a prior outage at Waringstown, or a secondary outage whilst the 33 kV system was being operated radially during this time. Whilst acceptable approach to ensure compliance, this is not sustainable in the longer term.

Additionally, the Armagh 33 kV network is currently at risk of voltage excursion under N-1 conditions. In future due to forecast electrification of heat and transport there is also expected to be a risk of overloading under N-1 conditions. An outage on any one of the four circuits supplying this area during peak load periods results in thermal overloading and/or low voltages on the remaining sections of 33 kV circuits ‘in service’.

Options 2 and 3 involved establishing a second substation at Drumnakelly Main and reinforcing the Armagh 33 kV distribution network by constructing new 33 kV overhead line circuits and rebuilding existing 33 kV circuits.

Option 4 was the establishment of a new 110/33 kV substation at Armagh Central (an existing 33 kV substation) connected to Tandragee Main via two new monopole (Trident) 110 kV overhead line circuits. This was found to comply with the standards and have a significant scheme life and mid-range cost.

Option 5 was not shortlisted because with it only having a single circuit it did not meet the voltage step change limits even for normal switching operations.

Option 6 and Option 7 (Connection of a new Armagh Central BSP to the proposed Turleenan 400/275 kV substation or Turleenan – Woodland 400 kV circuit) were also not shortlisted because they were more than twice the cost of Option 4 for example (three times for Option 7). For both options it is unlikely that a convincing case of need for such a development of this scale could have been made. Whilst slightly shorter distance in terms of new 110 kV overhead lines, this was marginal and would not justify the increased cost and other difficulties.

Option 8 was twice as expensive as Option 4. Additionally, these cables would require compensation through teed shunt reactors to each cable circuit and this would require an extension of Tandragee substation to site the new shunt reactors. This option was also technically inferior due to complexity in managing long cables, susceptibility to third party damage and repair times. Any improvements to deliverability of this option were not apparent, and it was therefore not shortlisted.

The four short-listed options considered in this report are:

- Option 1 - Do nothing;
- Option 2 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and new Tullygoonigan Richill 33 kV ring;
- Option 3 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and rebuild existing Tullygoonigan Richill 33 kV circuit; and
- Option 4 - Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits.

The appraisal of the shortlist focused on the lifecycle and environmental impact of the remaining options.

With Option 1 - Do Nothing, as demand continues to rise, due to electrification of heat and transport, the frequency at which the remaining ‘in-service’ 33 kV circuits will be at risk will increase significantly. Value of Lost Load (VoLL) analysis has been completed

using load index data of the Armagh Area 33 kV system, historic data on outages and maintenance duration for the four circuits and other assumptions. This has determined that without reinforcement the overall total cost of VoLL from faults, maintenance and during normal system operation from 2024-2064 is estimated to be £258.93m.

The assessment based on uptake of LCT was that Options 2 or 3 could be out of standard by the time any one of the two are built and would have no scheme life. A replacement would need to be through planning and ready for construction. In this case given that Option 4 is assumed as the next step, then the second 110/33 kV substation at Drumnakelly Main would not be needed and clearly nugatory.

Based on a multi-criteria analysis of capital and lifecycle costs, technical merit, deliverability and environmental impact, the preliminary preferred option is identified as Option 4. Option 4, estimated to cost £29.43m, introduces a new bulk supply point into the heart of the Armagh region and diverts just under half the demand away from Drumnakelly Main also relieving the issues there. It is the optimum solution when considering additional demand growth resulting from the decarbonisation of heat and transport.

It is proposed to use a monopole design for the two overhead line circuits to minimise the visual impact and cost. It also requires an extension of the substation arrangement at Tandragee Main to accommodate two additional 110 kV double busbar bays. To establish a standoff area at Armagh Central BSP (standard design approach at 110/33 kV substations), a strip of land will need to be purchased around the existing substation. This land purchase has been priced and included in the overall option cost.

An environmental report has been completed to assess the impact of the proposed shortlisted options. The preferred option is ranked second in this study.

Considering the Lifecycle costs of the shortlisted options, although initially the capital cost investment is higher, Option 4 is the least cost option from the Net Present Cost assessment at £29.56m. Option 2 and Option 3 consider the capital cost of Option 4 for future reinforcement works, as well as the initial capital cost for reinforcing the distribution system now. This results in a higher Net Present Cost.

It is therefore considered prudent to progress with Option 4 as preferred option to provide long term system security in the Armagh area. For the purposes of our

stakeholder consultation and TNPP submission this is selected as the preliminary preferred option.

1 Introduction

The need for the reinforcement of the transmission and distribution systems in the Armagh and Drumnakelly areas has been confirmed in the associated Needs Report.

NIE Networks has identified that at times of high electrical demand in the Armagh area, the firm capacity of the 33 kV distribution network is exceeded. The distribution network supporting the demand in this area of Armagh is supplied from Drumnakelly. Demand at Drumnakelly is just below the nominal rating of the 110/33 kV transformers. Based on the NIE Networks demand forecast, the site remains within the cyclic overload rating of the transformers up to 2032 (estimated at a further 13.5% in winter). However, after 2032 the forecasted demand exceeds this rating and a post fault demand transfer to Waringstown would be required to ensure the site remains compliant with TSSPS and DSSPS. This would require the automatic disconnection of load until the transfer takes place to prevent overloading the remaining in-service transformer. Whilst this would meet the minimum requirements of the standards it does involve additional risk to supplies and provides no capacity for future load growth.

Additionally, for the loss of one of the four 33 kV circuits from Drumnakelly that supply the Armagh distribution system (N-1 contingency) the remaining 33 kV circuits are at risk of overload and can exceed statutory voltage limits. With forecasted demand figures likely to make the occurrence of these issues more prominent, it is necessary to reinforce the transmission and distribution network supplying Armagh to ensure compliance.

2 Description of the network

Drumnakelly Main 110/33 kV Bulk Supply Point (BSP) is comprised of an eight bay 110 kV air insulated switchgear (AIS) mesh, two 90 MVA 110/33kV transformers and a 33 kV 2000A switchboard which supplies the Portadown, Craigavon and Armagh demand centres. This substation is connected to the transmission system via two 110 kV circuits to Tamnamore Main Grid Supply Point (GSP) and three 110 kV circuits to Tandragee Main GSP.

Just under half of the power delivered from Drumnakelly Main is used to supply the Armagh city and surrounding towns and villages via four 33 kV circuits (a combined total of 138 km of overhead line) which operate in parallel. This network in turn supplies eight 33/11 kV primary substations, including two substations that supply Armagh city, shown below in Figure 1. The two central 33 kV circuits (shaded in figure 1) are constructed with 200 mm^2 conductor, the highest capacity 33kV design. These circuits are supported by a further two lower capacity circuits feeding the area through 33/11 kV substations in Richhill and Markethill. Network security is maintained based on three out of the four circuits remaining operational at all times.

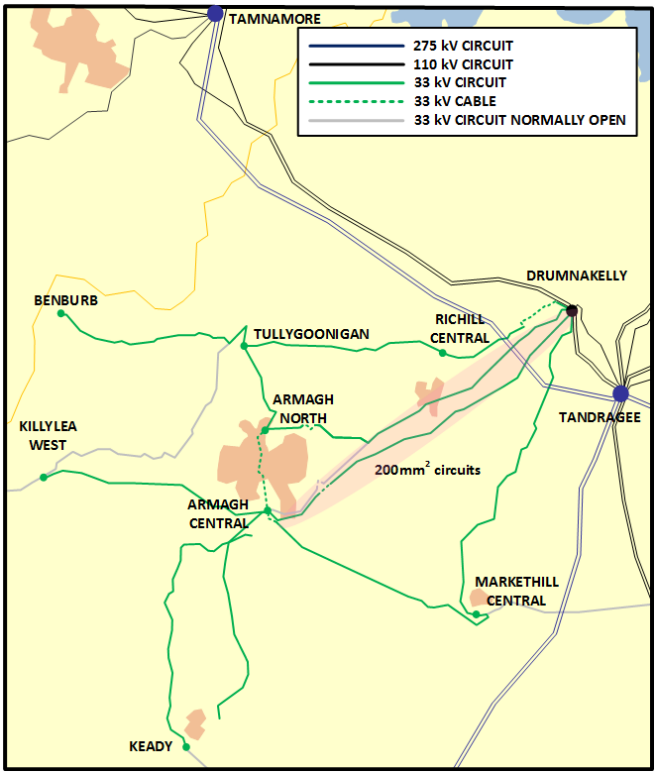

Figure 1 - Distribution network in Armagh area

3 Long list of options

3.1 Option 1 – Do Nothing

This option is to do nothing.

3.2 Option 2 - Second Bulk Supply Point (BSP) at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and new Tullygoonigan Richill 33 kV ring (£23.90m)

This option would comprise the following components:

- Establishment of a second 110/33 kV substation (with two new 90 MVA 110/33 kV transformers) near to the existing Drumnakelly Main substation.
- Construction of a new 33 kV circuit from Drumnakelly Main to Tullygoonigan.
- Complete rebuild of existing 33 kV circuits from Drumnakelly to Richhill and Richhill to Tullygoonigan.
- Construction of a new 33 kV circuit from Drumnakelly Main to Armagh Central.

This work is estimated to cost £23.90m in total (see cost estimate in Appendix 1-1).

3.2.1 Second 110/33 kV substation at Drumnakelly

The second 110/33 kV substation would be developed on land owned already by NIE Networks adjacent to the current substation, see Figure 2 with land identified in red.

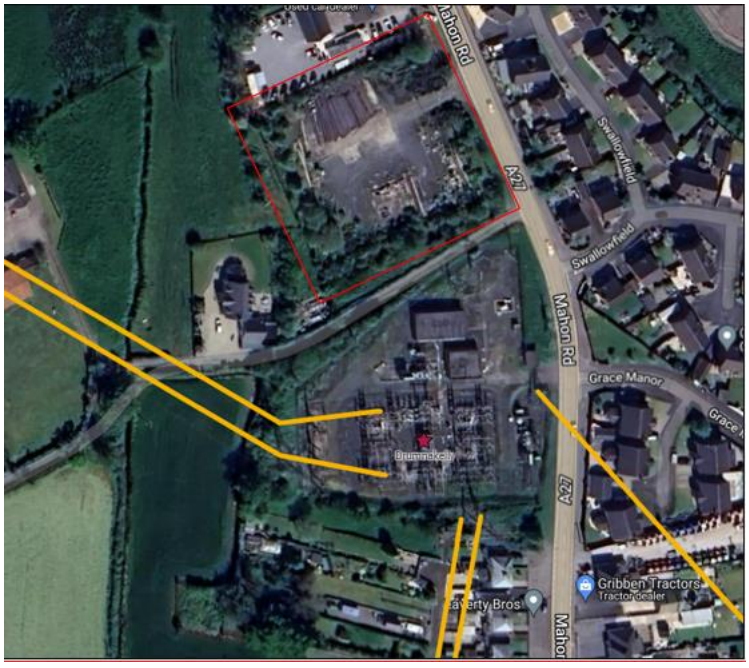

Figure 2 – Lands owned by NIE Networks North of Drumnakelly Main

This would require the existing 110 kV mesh to be extended by two bays to connect two new 110/33 kV transformers, see Figure 3. A new 33 kV switchboard would be established at the new site and all 33 kV circuits supplying Armagh would be diverted into the new 33 kV switchboard. This would address the capacity issue at Drumnakelly Main.

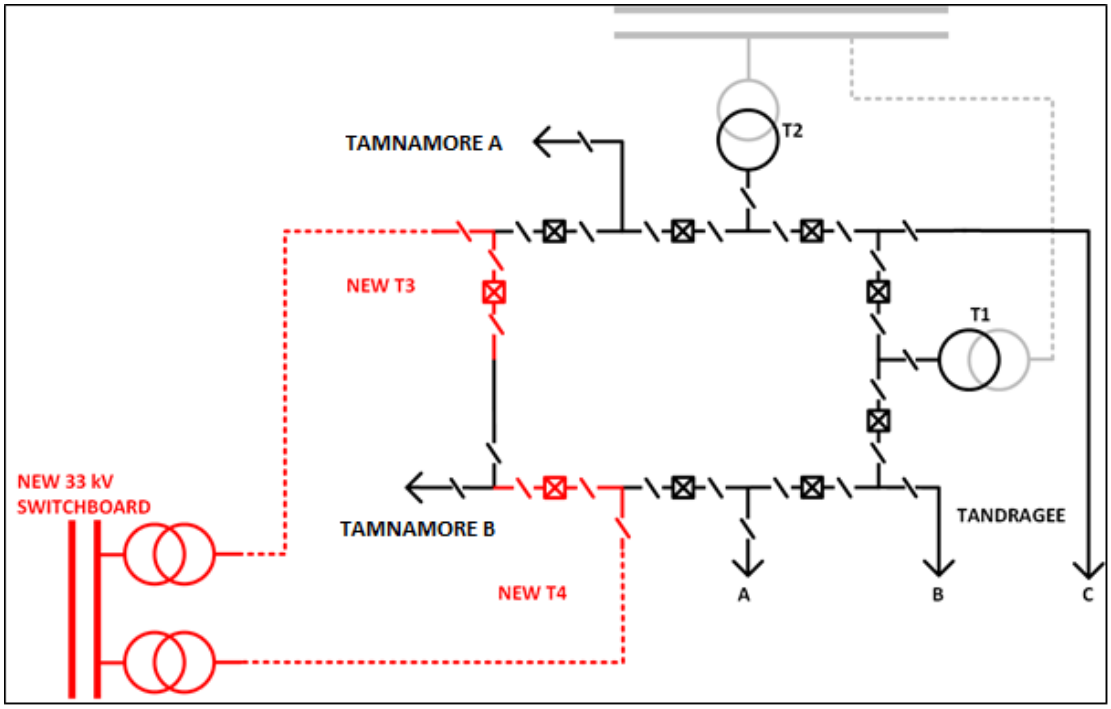

Figure 3 - Option 2 110 kV reinforcement – 110 kV mesh extension at Drumnakelly

3.2.2 33 kV Reinforcement

This option allows for the construction of a new 33 kV circuit from Drumnakelly Main to Tullygoonigan (approx. 15km) to establish a new 33 kV ring system between Drumnakelly, Richill Central, Tullygoonigan and Benburb. In addition to this new 33 kV circuit, the Drumnakelly – Richhill – Tullygoonigan 33 kV circuit would be rebuilt and replaced by a new 200mm^2 circuit on a new alignment as long-term outages to upgrade the existing circuits are not feasible.

This option would also require a new 200mm^2 33 kV circuit from Drumnakelly to Armagh Central (approx. 18.2km). The schematic is shown in Figure 4.

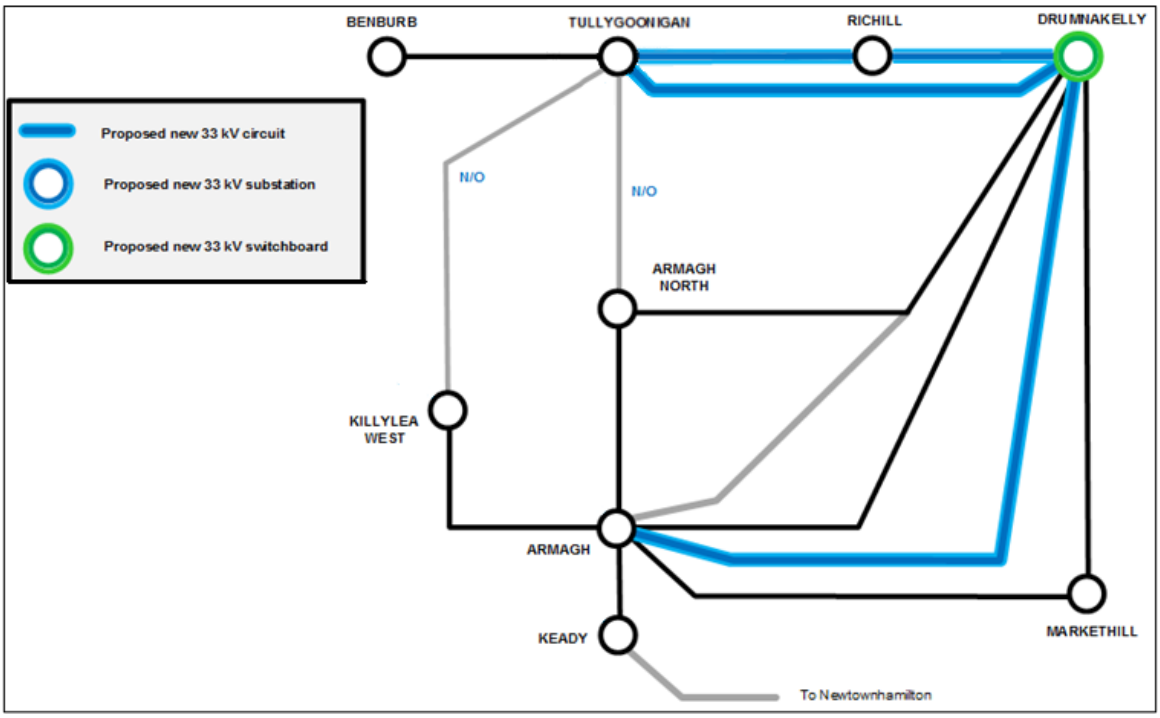

Figure 4 – Option 2 33 kV reinforcement – new 33 kV circuits in Armagh area network

With the new 33 kV circuit from Drumnakelly to Tullygoonigan, a normally open point (N/O) would be established between Armagh North and Tullygoonigan. As a result, Richill Central and Tullygoonigan would operate on a dedicated 33 kV ring fed out of Drumnakelly with Benburb being supplied via a 33 kV spur from this new ring network.

The two existing and the one new 200 mm^2 ACSR 33 kV circuits from Drumnakelly to Armagh Central, and the 75 mm^2 ACSR 33 kV circuit between Drumnakelly and Markethill would become the new Armagh distribution system.

3.3 Option 3 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and rebuild existing Tullygoonigan Richill 33 kV circuit (£20.85m)

This option would comprise the following components:

- Establishment of second 110/33 kV substation (with two new 90 MVA 110/33 kV transformers) near to the existing Drumnakelly Main substation.
- Complete rebuild of existing 33 kV circuits from Drumnakelly to Richhill and Richhill to Tullygoonigan.
- Construction of a new 33 kV circuit from Drumnakelly Main to Armagh Central.

This work is estimated to cost £20.85m in total (see cost estimate in Appendix 1-2).

3.3.1 110/33 kV substation

The new 110/33 kV substation would be as per Option 2 - see section 3.2.1.

3.3.2 33 kV reinforcement

This option would be based on establishing a new 33 kV circuit between Drumnakelly Main and Armagh Central (approx. 18.2km) and rebuilding the existing 14.1km Drumnakelly – Richhill – Tullygoonigan 33 kV circuit to 200mm² on a new alignment (due to it not being feasible to obtain a long-term outage to rebuild the existing circuit). All circuits would operate in parallel. The resulting configuration is shown in Figure 5.

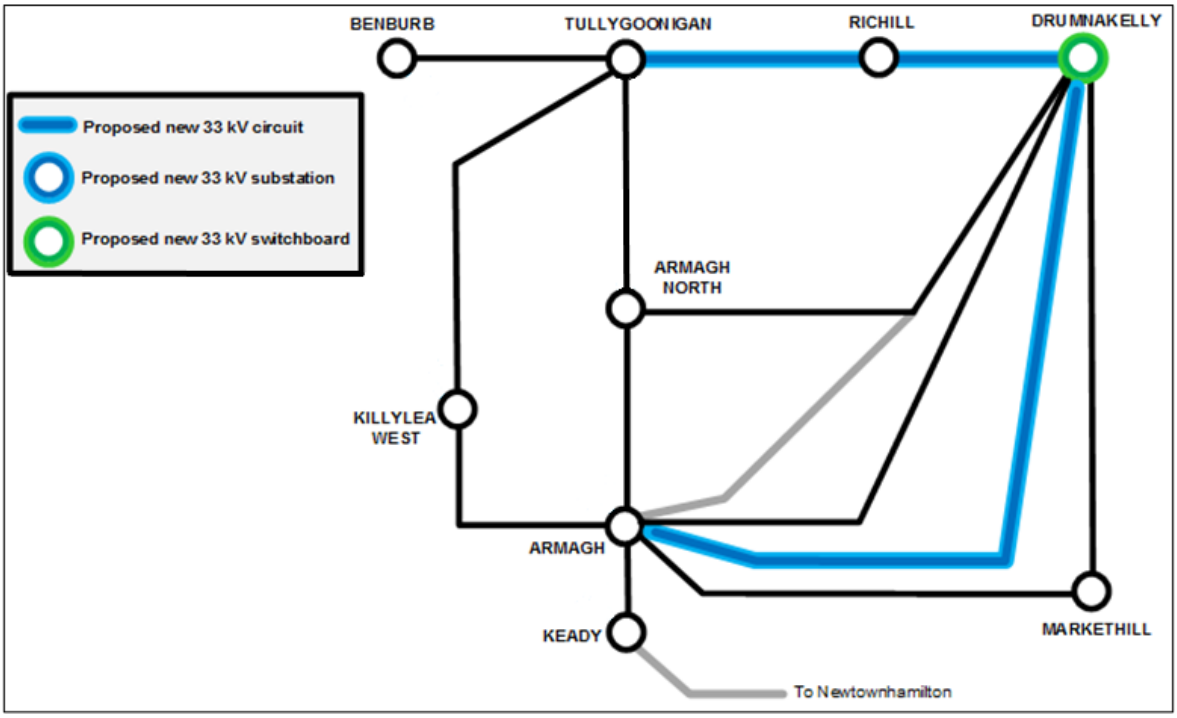

Figure 5 - Option 3 33 kV Reinforcement - new 33 kV circuits in Armagh area network

3.4 Option 4 – Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits (£29.43m)

This option would comprise three elements:

- Extension of the Tandragee Main 110 kV compound and construction of two additional bays.
- Establishment of a new 110/33 kV substation (with two new 90 MVA 110/33 kV transformers) at Armagh Central via two new 110 kV circuits from Tandragee.

- Reconfiguration of the 33 kV network to be supplied from the new 110/33 kV substation.

This work is estimated to cost £29.43m in total (see cost estimate in Appendix 1-3).

Studies show that this scheme would provide significant spare capacity and secure the demand at Drumnakelly and Armagh for the long term.

3.4.1 110/33 kV substation at Armagh

Armagh Central would be an optimal location for the establishment of a new 110/33 kV substation to supply the Armagh 33 kV network due to the following:

- Armagh Central has five outgoing 33 kV circuits providing an ideal site to develop as a new power infeed;
- Armagh Central is the most heavily loaded 33/11 kV substation on this 33 kV system;
- Together with Armagh North, the second highest loaded substation which is approx. 3.8 km from Armagh Central, the total demand summates to circa 20 MVA;
- There is space available around the Armagh Central substation for its expansion to accommodate the proposed transmission plant; and
- The 33 kV mesh at Armagh Central has been recently replaced with a 33 kV switchboard that has been specified for 110/33 kV transformer incomers.

It is proposed to have a duplicate transformer feeder arrangement at Armagh. This avoids the need to establish 110 kV switchgear which would save on the cost and space requirements at Armagh Central. It is good industry practice for duplicate transformer feeders to be supplied from the same source as this means there are no power angle differences and both feeders behave identically[1].

[1] A design involving one circuit from Tandragee Main and one circuit from Drumnakelly Main was considered. However, this was not chosen because transformer feeders should not be supplied from alternative sources which would allow power to circulate through the 33 kV busbars. The circulation of power in this manner would have the potential to overload these parts of the network that are not rated for the larger 110 kV backbone flows.

A land purchase will be required around the existing Armagh Central substation to establish a standoff area (a common design practice to ensure safety at 110/33 kV substations). This land purchase has been priced and included in the overall option cost.

3.4.2 Extension of Tandragee Main

The 110 kV arrangement at Tandragee Main is shown in Figure 6. New equipment is indicated in red.

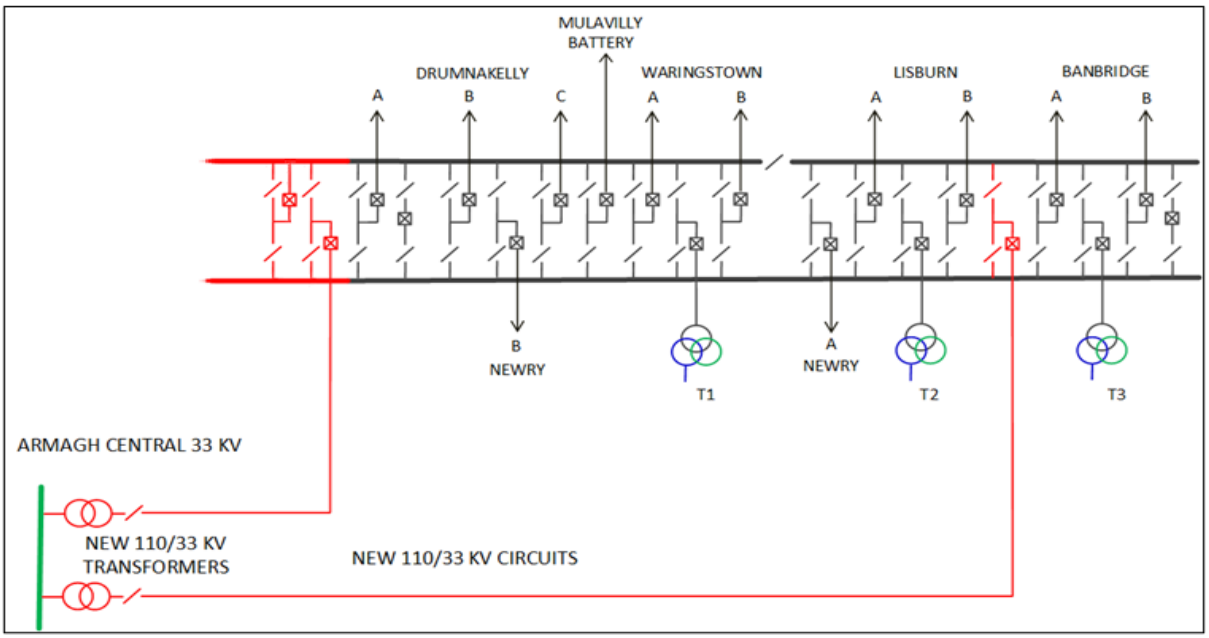

Figure 6 - Option 4 110 kV Reinforcement – 110 kV extension at Tandragee for connection of Armagh BSP

To accommodate the new 110 kV circuits a compound and busbar extension would be required. This will create two new 110 kV bays between the existing substation boundary and the battery customer connected at Mullavilly substation (these lands are owned by NIE Networks). Tandragee Main has one existing spare 110 kV bay. The spare and new 110 kV bays will be used to connect the new 110 kV circuits (to enable this to take place an existing feeder will be swapped with one of the new Armagh Central circuits).

3.4.3 110 kV overhead line design

It is proposed that the new overhead line circuits between Armagh Central and Tandragee Main will be constructed with a monopole design (approx. 18.3km each), for both visual impact and cost reasons. Further information on monopole design is provided later in this report.

If is determined that an approach to Armagh Central via overhead line is not feasible then using the route of two existing 33 kV overhead lines circuits could be considered. The impacted sections of 33 kV circuits would be undergrounded. If this is not feasible then the new 110 kV circuits will be cabled into Armagh substation.

Additionally due to the congestion of overhead line circuits near Tandragee substation it is assumed that the new circuits will be cabled into the substation. An overall allocation of 3km per circuit (6km total) is provided in the cost estimate for this option.

3.4.4 33 kV reinforcement

To maximise the benefit of a new 110/33 kV site at Armagh Central, the existing 33 kV feeding arrangements would be modified as follows:

- A 33 kV cable circuit (approx. 5.7km) would be established between Armagh Central and Armagh North; and
- Reconfiguration of the network to establish a new 33 kV circuit from Armagh Central to Tullygoonigan, bypassing Armagh North.

The result of this work would be to secure the Armagh North substation on a short underground dedicated ring with the rural Tullygoonigan and Benburb substations supplied from Armagh Central by a new 33 kV ring circuit. Richhill would remain supplied from Drumnakelly Main. Additionally, auto-changeover schemes would be established at Richhill and Markethill substations. This arrangement is shown in Figure 7.

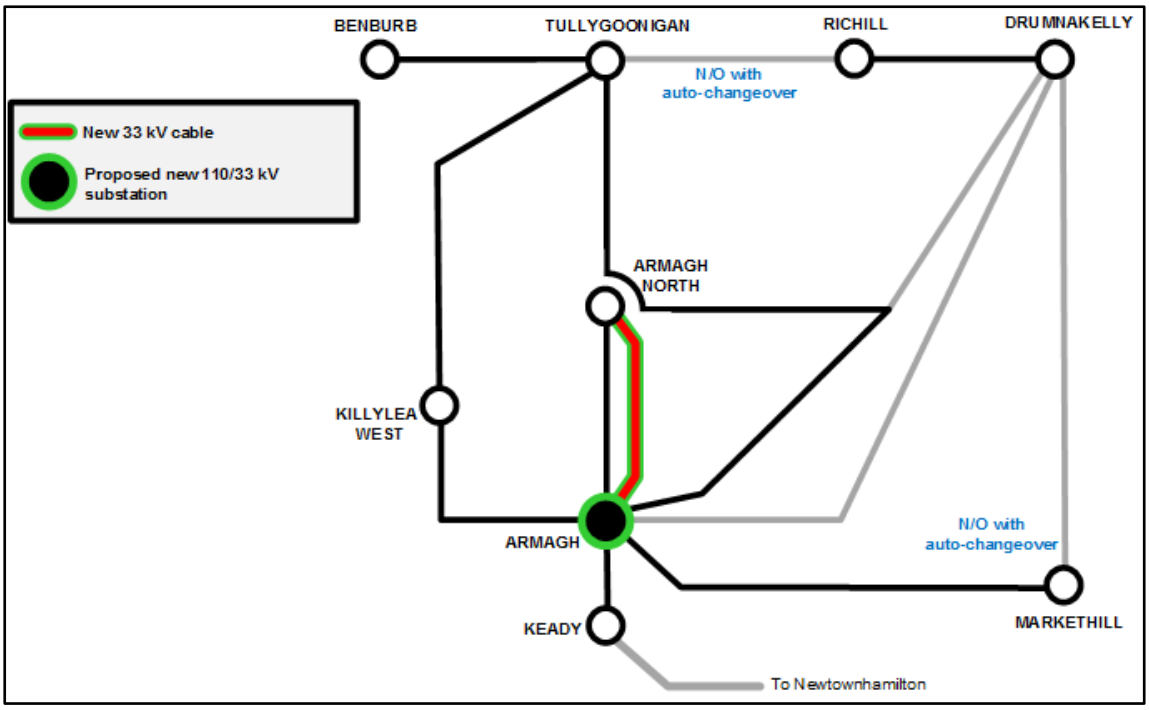

Figure 7 - Option 4 33 kV Reinforcement – new 33 kV cable in Armagh and auto-changeover schemes

3.5 Option 5 - Connection of a new Armagh Central BSP to Tandragee via one new monopole single 110 kV circuit (£13.81m)

This option would comprise two elements:

- Equipping a spare bay at Tandragee 110 kV substation with 110 kV switchgear for a new circuit.
- Establishment of a new 110/33 kV substation (with one new 90 MVA 110/33 kV transformer) at Armagh and supplied by a new 110 kV circuit fed from Tandragee.

This work is estimated to cost £13.81m in total (see cost estimate in Appendix 1-4).

3.5.1 110 kV reinforcement:

Tandragee Main has an existing spare bay in the 110 kV arrangement. This bay is currently unequipped and would require switchgear. The 110 kV arrangement at Tandragee Main is shown in Figure 8. New equipment is indicated in red.

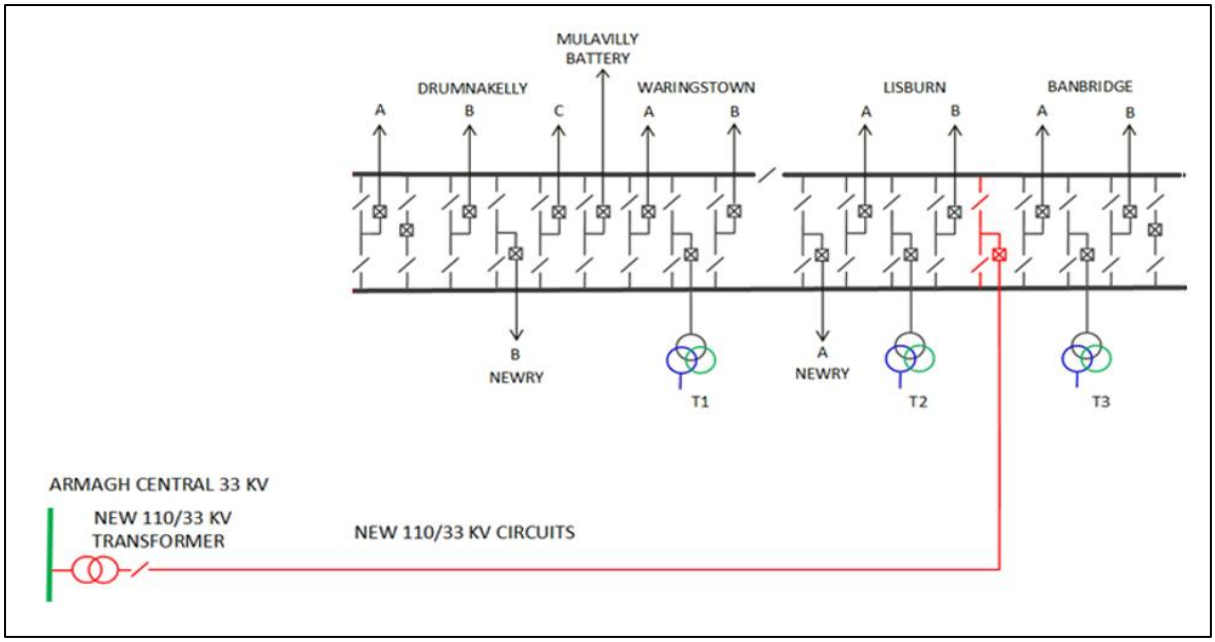

Figure 8 – Option 5 110 kV Reinforcement – 110 kV extension at Tandragee for connection of Armagh BSP

Similar to option 4, it is proposed that a new 110 kV overhead line circuit would be constructed of predominantly monopole overhead line design (approx. 18.3km), for visual and cost reasons. An allocation of 3km of underground cable is provided in the cost estimate of this option due to the congestion of overhead line circuits near Tandragee substation and if substation entry is not possible via overhead line at Armagh Central.

3.5.2 33 kV reinforcement

The 33 kV arrangement for this option is slightly different to Option 4, as the new 110 kV circuit supplying Armagh Central 110/33 kV BSP would be operating in parallel with the existing 33 kV circuits to supply Armagh City and the remainder of the distribution substations back towards Drumnakelly. The resulting configuration is shown in Figure 9.

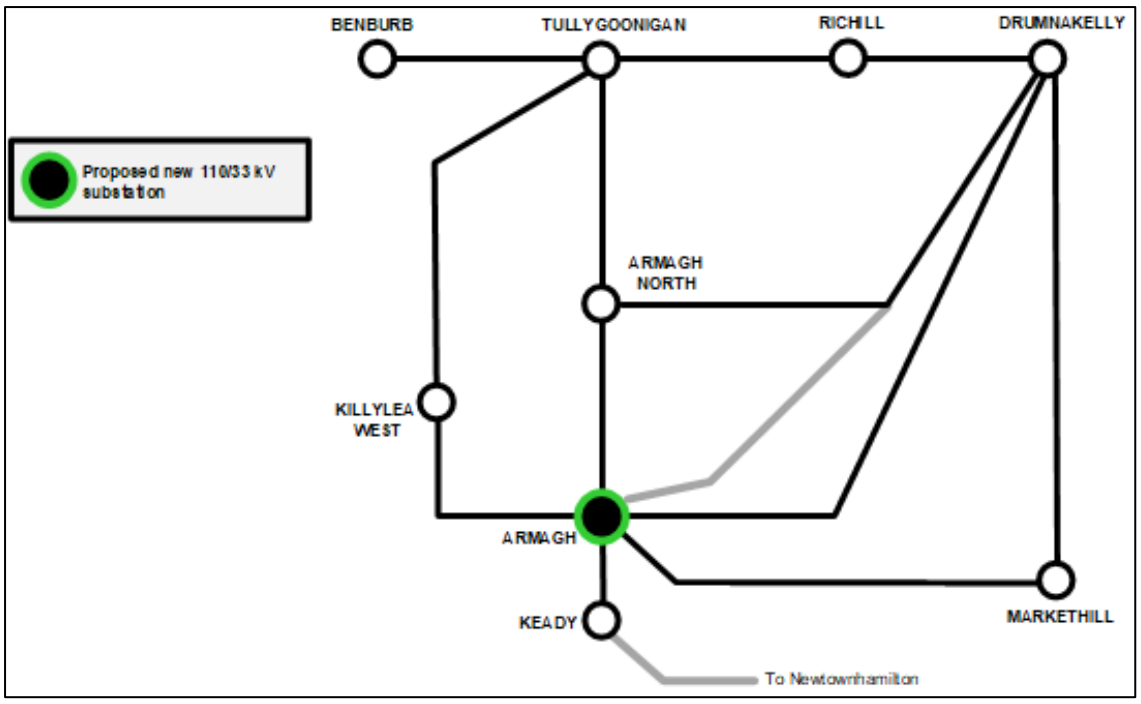

Figure 9 – Option 5 - 33 kV arrangement between the new Armagh Central 110/33 kV BSP and Drumnakelly 110/33 kV BSP

3.6 Option 6 - Connection of a new Armagh Central BSP to the proposed Turleenan 400/275 kV substation (£62.89m)

This option is based on establishing a new 110/33kV substation at Armagh Central connected to an expanded Turleenan. It would comprise the following elements:

- Land purchase at the proposed Turleenan 400/275 kV substation (part of the North South interconnector project);
- Extension of Turleenan compound and install two new 275/110 kV interbus transformers and a new 110 kV double busbar arrangement;
- Possible extension of the proposed 275 kV GIS switchboard at Turleenan;
- Establishment of a new 110/33 kV substation (with two new 90 MVA 110/33 kV transformers) at Armagh and supplied by two new 110 kV circuits fed from Turleenan.
- Reconfiguration of the 33 kV network to be supplied from the new 110/33 kV substation.

This work is estimated to cost £62.89m in total (see cost estimate in Appendix 1-5).

3.6.1 400, 275 and 110 kV reinforcement:

Armagh Central remains the optimal location for a new BSP as discussed in previous options. However, this option would require a significant substation extension at the proposed Turleenan 400/275 kV substation site. This is needed to establish two 275/110 kV interbus transformers and a 110 kV AIS double busbar.

From the new 110 kV double busbar arrangement two new 110 kV circuits would be constructed to Armagh central, approx. 19km each. Monopole overhead line construction would be proposed due to the cost, visual and capacity reasons described in previous options. An allocation of 4km dual underground cable section would be required for the two new circuits to route through Armagh city to Armagh Central BSP.

3.6.2 33 kV reinforcement

The new 33 kV arrangement in the Armagh area network would be as per Option 4 - see section 3.4.4.

3.7 Option 7 - Connection of a new Armagh Central BSP to the proposed Turleenan – Woodland 400 kV circuit (£99.08m)

This option is based on establishing a new 400 kV switching station along the route of the proposed North South interconnector to supply the new bulk supply point at Armagh. It would comprise the following elements:

- Land purchase along the proposed Turleenan - Woodland 400 kV circuit (North South interconnector project), pre-enabling and establish 400, 275 and 110 kV AIS double busbar arrangements.
- Turn in of the Turleenan – Woodland 400 kV circuit and supply the 275 kV arrangement via two 400/275 kV interbus transformer and supply the 110 kV arrangement via two 275/110 kV interbus transformer.
- Establishment of a new 110/33 kV substation (with two new 90 MVA 110/33 kV transformers) at Armagh and supplied by two new 110 kV circuits fed from the new 400/275/110 kV substation.
- Reconfiguration of the 33 kV network to be supplied from the new 110/33 kV substation.

This work is estimated to cost £99.08m in total (see cost estimate in Appendix 1-6).

3.7.1 400, 275 and 110 kV reinforcement:

Armagh Central remains an optimal location for a new BSP as discussed in previous options. This option would require a turn in of the proposed Turleenan – Woodland 400 kV circuit at a location closer to Armagh Central for any benefits to be obtained. It is likely

that the chosen site would be west to south-west of Armagh City. A significant land purchase would be required to establish 400, 275 and 110 kV AIS double busbar arrangements, the turn in of the 400 kV circuit and the siting of two 400/275 kV interbus transformers and two 275/110 kV interbus transformers to supply the three voltage levels. However, an option of stepping down directly from 400/110 kV would be considered.

From the new 110 kV double busbar arrangement two new 110 kV circuits would be constructed to Armagh central, approx. 12.2km each. Monopole overhead line construction would be proposed due to the cost, visual and capacity reasons described in previous options. An overall allocation of 1km per circuit (2km total) is provided in the cost estimate for this option for substation entry at Armagh Central if required.

3.7.2 33 kV reinforcement

The new 33 kV arrangement in the Armagh area network would be as per Option 4 - see section 3.4.4.

3.8 Option 8 - Connection of a new Armagh Central BSP to Tandragee via two new underground cable 110 kV circuits (£64.04m)

This option is similar to Option 4 except it would be developed via underground cables. It would comprise three elements:

- Extension of the substation boundary at Tandragee 110 kV substation and construction of two additional bays.
- Land purchase and diversion of sterile zone at Tandragee to establish a new shunt reactor compound.
- Additionally, install and connect teed onto each new 110 kV cable circuit a 30 Mvar shunt reactor (2No. total) for cable circuit compensation.
- Establishment of a new 110/33 kV substation (with two new 90 MVA 110/33 kV transformers) at Armagh and supplied by two new 110 kV underground cable circuits fed from Tandragee.
- Reconfiguration of the 33 kV network to be supplied from the new 110/33 kV substation.

This work is estimated to cost £64.04m in total (see cost estimate in Appendix 1-7).

3.8.1 110 kV reinforcement:

Armagh Central remains the optimal location for a new BSP as discussed in previous options. This option proposes to connect the Armagh Central 110/33 kV substation to Tandragee via underground cable circuits approx. 20.5 km in length. A desktop study has

determined that both circuits can utilise a dual cable trench arrangement for the new cable route between Armagh Central and Tandragee Main, see Figure 10 below. This dual cable circuit route would predominantly use the existing road network where possible.

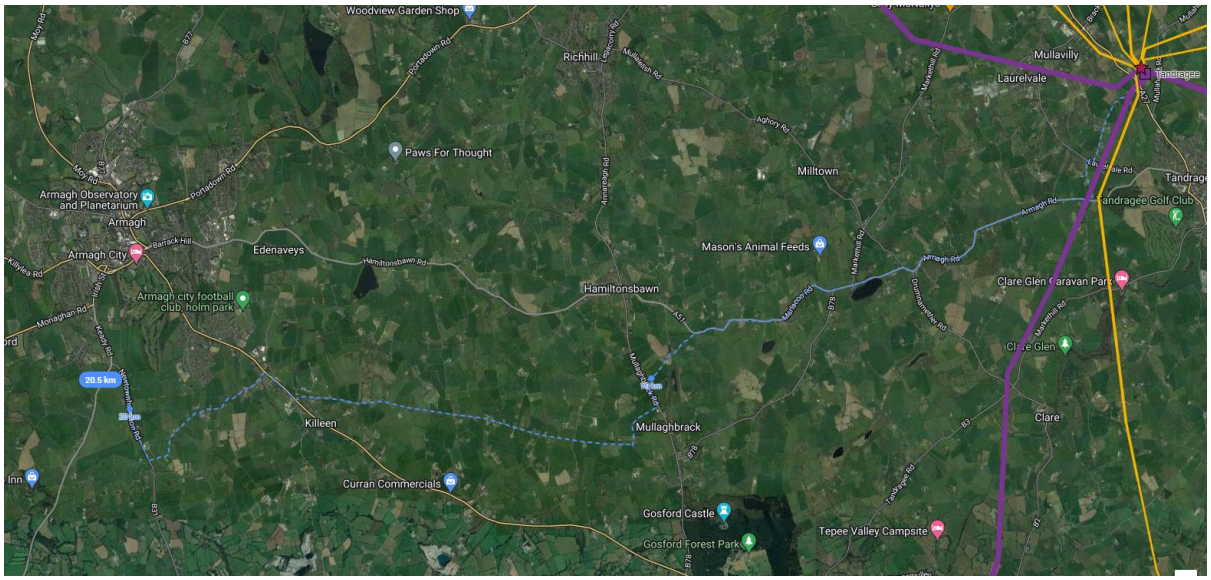

Figure 10 - Desktop study of indicative dual cable route identified in blue

Two approx. 20.5km 110 kV underground cable circuits will inject reactive power into the Tandragee node. This would have the impact of increasing the voltage, in particular at night when the system is lightly loaded. To compensate for this two new 30 Mvar shunt reactors would be required. These would be directly teed onto each cable circuit so they are switched in at the same time.

At Tandragee a land purchase and a site extension would be required to accommodate an extension of the existing 110 kV double busbar arrangement and for the additional reactive compensation discussed above. This would create two new 110 kV bays between the existing substation boundary and the battery customer connected at Mullavilly substation (these lands are owned by NIE Networks). Tandragee Main has one existing spare 110 kV bay. The spare and new 110 kV bays would be used to connect the new 110 kV cable circuits (to enable this to take place an existing feeder would be swapped with one of the new Armagh Central circuits). The shunt reactors would also be teed onto each cable circuit.

For comparison this option is more than twice the cost of Option 4 which is the similar twin 110 kV circuit reinforcement using monopole overhead line circuits.

3.8.2 33 kV reinforcement

The new 33 kV arrangement in the Armagh area network would be as per Option 4 - see section 3.4.4.

4 Appraisal of long list

4.1 Technical

4.1.1 Option 1 - Do nothing

This option would result in an eventual lack of capacity at both Drumnakelly 110/33 kV substation and on the 33 kV system that supplies Armagh.

Transmission capacity:

At the Drumnakelly Main site the cyclic overload rating has been estimated at 95.4 MVA (106%) and 102.15 MVA (113.5%) in summer and winter respectively. This has been assessed based on the actual demand profile and typical transformer parameters.

Based on the demand forecast for Drumnakelly Main, the peak demand on the winter peak day, whilst exceeding the 90 MVA rating of the transformers, would be within the cyclic rating of the transformers up to about 2032. Loading beyond cyclic rating results in increased aging over the long term. Additionally, the 33 kV switchboard is rated to 2000A, indicating an upper limit of 114 MVA.

Beyond 2032 a conservative approach would be to change the normal system operation on the 33 kV system to transfer demand permanently off Drumnakelly Main. However, this is unlikely to achieve sufficient management of the issue, as the problem would be passed onto Waringstown. The DSSPS and TSSPS however would allow for a post fault transfer to Waringstown Main to avoid thermally overloading the remaining in-service transformer. It would be necessary to operate this 33 kV network radially during this time. If that radial operation was prolonged that would imply a certain risk to supplies, for example in the event of second outage. However, whilst this scheme needs to be in place it is unlikely to ever be required because transformer faults are rare and this would have to occur at peak demand in Winter.

The DSSPS and TSSPS allows for up to 20 MW to be disconnected initially and then transferred within 3 hours. This could be supported, if necessary, by the automatic disconnection of load to allow sufficient time for the transfer.

In conclusion, initially the cyclic overload rating would be used, and then post fault transfer to maintain compliance. However, whilst allowed in the TSSPS and DSSPS, this approach does involve greater risk, for example in a second failure or programmed

outage. They are also more difficult to manage over the long term and this approach provides no capacity for future load growth.

Armagh Area 33 kV network issues:

Additional to these issues discussed at Drumnakelly, the existing demand on the Armagh 33 kV network is in excess of its firm capacity, i.e. based on the capacity of three of the four circuits remaining operational. Whilst the system, at present, remains technically within the minimum-security requirements for C2[2] class of supply of the DSSPS the service level is well below what is normally provided. However, in future years it is expected to become non-compliant with the standard.

The firm capacity of the four 33 kV circuits supplying Armagh City and surrounding area is 40 MVA (based on the most onerous 33 kV single circuit outage). In 2021/22 the peak network load was approximately 109% of the system's firm capacity and in winter 2021/22 the system demand was in excess of the firm capacity for a total of 136 hours.

Based on NIE Networks' forecast the total demand on the network expected to increase to 132% of firm capacity by the end of RP7 (2031) and the system demand risks being in excess of the firm capacity 1915 hours per year by the end of RP7 (2031). An outage on any one of the four circuits at peak load periods results in thermal overloading or low voltages on the remaining sections of 33 kV circuits 'in service'. Figure 11 below summarises these present and future issues.

[2] Under N-1 two thirds of group demand restored within 15 minutes and Group demand within 3 hours.

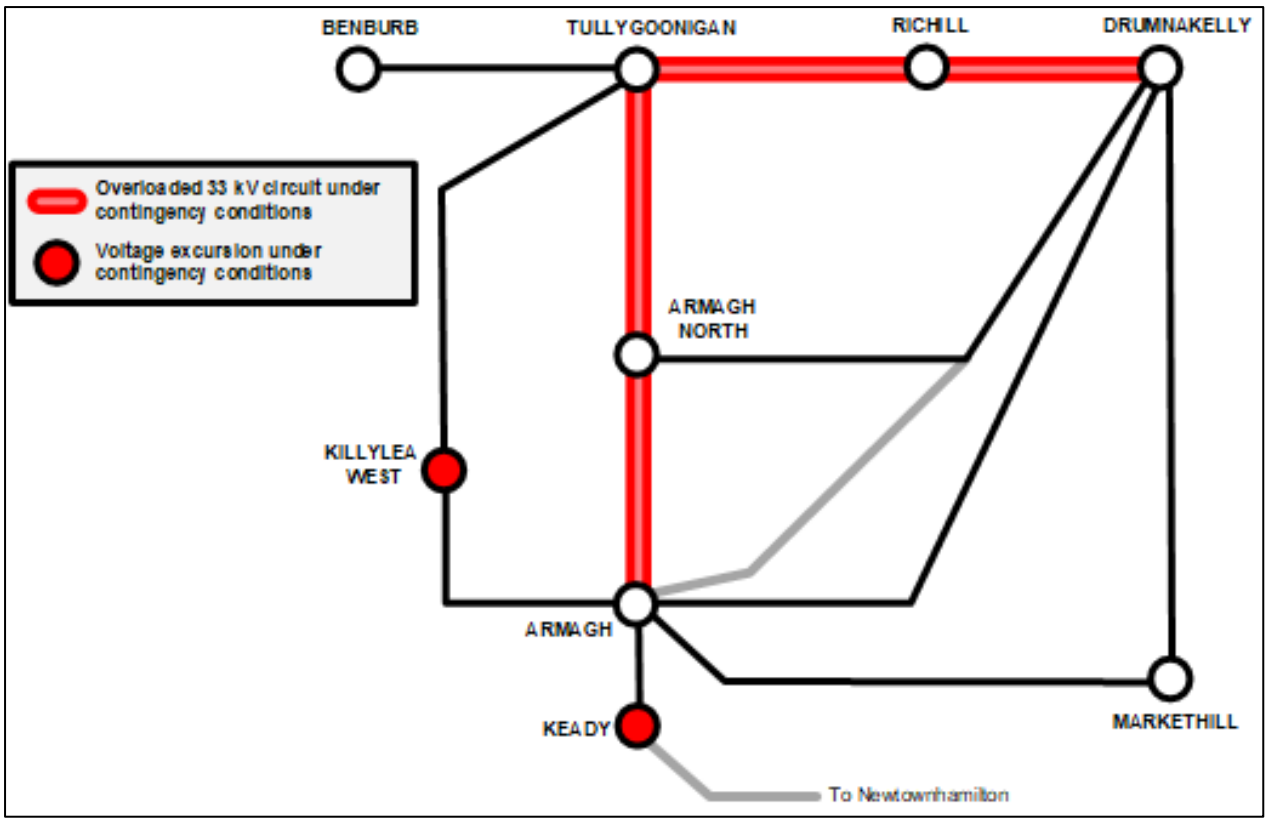

Figure 11 - Armagh Area 33 kV present and future network issues in contingency conditions

Unlike the emergency measures associated with the transformers at Drumnakelly and Waringstown, there is no overload capability for 33 kV overhead line circuits in the event of contingency. If overhead line circuits become overloaded, they pose a safety risk due to sag and can reduce safety distances and impede on anything below their path. Additionally, overhead line failures would be more common than a transformer failure as they are more naturally exposed to the environment and at risk of human error. As demand continues to rise the frequency at which the remaining 'in-service' 33 kV circuits will be at risk will increase significantly.

4.1.2 Option 2 – Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and new Tullygoonigan Richill 33 kV ring

The implementation of a second 110/33 kV substation including a new 33 kV switchboard at Drumnakelly, would provide additional 110/33 kV capacity for the long term.

Additional 33 kV circuitry between Drumnakelly and Armagh would address the risk of voltage and thermal issues, particularly on the Drumnakelly – Richill – Tullygoonigan ring. However, based on the forecasted demand growth, analysis has shown that, even if this option could be built beforehand it would be outside of standard by 2033. As it is not expected to be available until 2035, it would already be outside of standard before it is built and hence has no scheme life.

In fact, the analysis of Do Nothing shows that, based on the forecast uptake of LCT, there would already be loss of service at peak times and costs incurred due to VoLL in the several years before the scheme is implemented.

Additional voltage support in the form of capacitor banks could extend the life of this scheme. Capacitors installed on the distribution system inject reactive power locally to support the voltage. These are usually based on stepped banks that are switched in as required. The most economic option was to install capacitor banks at three 33/11 kV substations, namely Armagh Central, Killylea West and Keady Central. Killylea West and Keady Central both have existing 33 kV switchboards which, for this option, would require additional panels to facilitate the connection of the new capacitor banks.

However, based on the nature of the meshed 33 kV network in Armagh, with five substations connected solid, the installation of capacitor banks for voltage support at multiple primary substations creates a level of complexity and a risk of mis-operation. In addition, if the system becomes over-compensated there is a risk of sharp voltage collapse. Therefore, the use of capacitor banks for the long term would not be considered a prudent way forward, except for a short-term measure.

At this point SONI and NIE Networks would have to carry out further 33 kV reinforcement of the Armagh area or implement a transmission solution such as Option 4 and prudence would dictate that pre-construction for this scheme would have to be already underway rather than commenced in 2035. This would result in the Armagh area network remaining at risk for a significant period until the transmission solution is fully established. Additionally, it cannot be guaranteed that Option 4 would be as economically or technically viable as it is currently in this appraisal, due to the risk of increased total project costs and availability of bays for new circuits. It is estimated that if preconstruction was commenced prior to Option 2 being fully constructed (in 2033),

Option 4 would be delivered as additional reinforcement by 2042, resulting in the Option 2 works being nugatory investment.

4.1.3 Option 3 – Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and rebuild existing Tullygoonigan Richill 33 kV circuit

As discussed in option 2 (section 4.1.2), which has an identical transmission solution, the implementation of a second 110/33 kV bulk supply point including two new transformers and a 33 kV switchboard at Drumnakelly will address any issues in capacity for the long term.

Additional 33 kV circuitry between Drumnakelly and Armagh would address the risk of voltage and thermal issues. However, based on the forecasted demand growth, analysis has shown that this would be outside of standards by 2032. As it is not expected to be available until 2035, it would already be outside of standard before it is built and hence has no scheme life.

It is noted that a five-circuit network between Armagh Central and Drumnakelly would also present considerable difficulties regarding the set-up of protection. Analysis also shows that there would already be loss of service at peak times and costs incurred due to VoLL in the several years before the scheme is implemented. This would start to appear again in the years following, depending on the LCT uptake.

As discussed in option 2, the use of capacitor banks to extend the life of the scheme is not favoured due to complexity and reliability issues. Therefore, this scheme is only considered to address the voltage issues up to 2032.

At this point SONI and NIE Networks would have to carry out further 33 kV reinforcement of the Armagh area or implement a transmission solution such as Option 4 and prudence would dictate that pre-construction for this scheme would have to be already underway rather than commenced in 2035. This would result in the Armagh area network remaining at risk for a significant period until the transmission solution is fully established. Additionally, it cannot be guaranteed that Option 4 would be as economically or technically viable as it is currently in this appraisal, due to the risk of increased total project costs and availability of bays for new circuits. It is estimated that if preconstruction was commenced prior to option 2 being fully constructed (in 2032), option 4 would be delivered as additional reinforcement by 2041, resulting in the Option 3 works being nugatory investment.

4.1.4 Option 4 - Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits

The implementation of a 110 kV BSP node at Armagh Central, with two 110/33 kV transformers supplied by two 110 kV circuits from Tandragee Main would result in the transfer of demand, more than 40 MVA away from Drumnakelly. This would relieve Drumnakelly of demand and in that way address the shortfall in capacity over the long term. By establishing a new 110/33 kV bulk supply point into the heart of the 33 kV system in Armagh it also addresses the voltage and thermal issues there.

This design also avoids the need to establish 110 kV switchgear which would save on the cost and space requirements. It is good industry practice for duplicate transformer feeders to be supplied from the same source as this means there are no power angle differences and both feeders behave identically.

The new circuits would have a capacity of up to 144 MVA based on AAAC Upas conductor and underground cable sections, with the new transformers rated to 90 MVA. It is also noted that a capacity more than 144 MVA is not expected to be required as the area is not in the renewables pipeline. The 33 kV system at Armagh would be supplied from the new BSP and operated normally open from Drumnakelly. Drumnakelly would be offloaded releasing spare capacity.

Armagh Central is an ideal location for a 110/33 kV BSP. The existing 33 kV mesh at Armagh Central has been recently replaced with a new 33 kV switchboard that has been specified for 110/33 kV transformer incomers. The new 110/33 kV transformers can be installed within the existing Armagh Central compound. However, SONI would propose to purchase the lands surrounding the existing substation site to establish a standoff area. This is standard practice at rural 110/33 kV substations.

Overall, this option is technically superior. Studies show that this scheme would provide approximately 42 MW of spare capacity and with the current demand forecast would have a scheme life of greater than 40 years. The scheme would also provide improved resupply capability to relieve pressure faced at Newry substation (until such time as another transmission project can be taken forward to reinforce Newry Main).

4.1.5 Option 5 - Connection of a new Armagh Central BSP to Tandragee via one new monopole single 110 kV circuit

This arrangement would have a single 110 kV circuit supplying Armagh from Tandragee, with the 33 kV network operating in parallel with Drumnakelly. Normally bulk supply points are designed with two transformers and associated circuits for security of supply. Normally any 33 kV circuits that would interconnect to other bulk supply points would be operated normally open.

This design does not comply with planning standards in the event of an outage of either the 110/33 kV transformer at Armagh Central or the new 110 kV circuit the Armagh area. Studies have shown that the voltage step for the loss of the 110 kV circuit is in breach of TSSPS limits. Furthermore, the operation of a single transmission circuit in parallel with underlying distribution circuits is non-standard and results in operational concerns. For example, in the event of a loss of both transformers at Drumnakelly, say for a split mesh, both Armagh and Drumnakelly 33 kV demand blocks would be supplied from Armagh Central which would result in damaging voltage collapse and overload risks. A complex protection scheme would be required to detect this abnormal configuration and separate it.

As the option is non-compliant with planning standard requirements, it could not in its present format progress to the next stage. Further the changes required to make this solution compliant is the construction of a second 110 kV circuit which is essentially Option 4.

4.1.6 Option 6 - Connection of a new Armagh Central BSP to the proposed Turleenan 400/275 kV substation by establishing a Turleenan 110 kV substation

This option would involve installing two new 240 MVA 275/110kV transformers and a new 110 kV double busbar, essentially a new grid supply point, to supply a demand one sixth of that. The extension and modification of an extremely high voltage 400 kV substation such as the proposed Turleenan into a grid supply point for the reinforcement of a single local 33 kV system would be disproportionate.

It also involves the introduction of a third voltage level, i.e. 110 kV at Turleenan which would lead to physical congestion of cable and overhead line routes potentially inhibiting the purpose for which Turleenan is to be established, i.e. a strategic node for 275 kV and 400 kV.

A connection to the proposed Turleenan 400/275 kV substation is therefore inferior in terms of proportionate, practicality and operation.

4.1.7 Option 7 – Connection of a new Armagh Central BSP to the proposed Turleenan – Woodland 400 kV circuit

If the line was simply teed onto the proposed Turleenan to Woodland 400 kV overhead line then for any outage of the interconnector, supplies to Armagh would be lost. That would not be compliant with the planning standards.

If a full 400 kV switching station would be established, then for any N-1 on the line the Armagh node could continue to be supplied from either Turleenan in Northern Ireland or Woodland in Ireland. However, there would be unacceptable safety risks if this occurred during a routine parallel on the 33 kV systems between Armagh and Drumnakelly, say for moving a normally open point. The 33 kV system would then be acting as a secondary path for interconnection flows between two geographically distant transmission nodes, in two separate jurisdictions, with potentially large phase angle differences, which it is not designed for and pose a safety risk to operational staff on site.

For the reasons above a connection into the 400 kV interconnector itself has also been deemed technically unsound.

4.1.8 Option 8 – Connection of a new Armagh Central BSP to Tandragee via two new underground cable 110 kV circuits

The use of 110 kV cable of this length would require installation or additional tee connected shunt reactors at Tandragee Main to compensate for the reactive power created. Cable circuits of this length with tee connected shunt reactors can also trigger Zero-Miss Phenomena (ZMP) which may require Point on Wave (POW) switching and/or Pre-Insertion Resistor (PIR) to manage. These technologies are also challenging to keep in operating condition over longer periods of time.

Furthermore, cables of this length would have lower availability than an overhead line. This is because there would be a higher likelihood of third-party damage along the route of the cable from, for example road works etc. As standard design is to install duplicate cables in the same trench there is also a risk of double circuit fault from horizontal

directional drilling. Any damage to a cable requires a period of fault location to determine the point of fault. The faulted section is then cut out and replaced with a new section with two straight through joints on either side. A straight through joint requires a sterile and enclosed working area. It can be difficult to find jointing locations and the outage time to effectively repair is into several weeks if not longer.

Overhead lines are of course occasionally subject to the weather. However, weather related damage to a transmission overhead line is extremely rare and compared to a cable much easier to repair within days.

In conclusion whilst it would be technically feasible it would be vastly more complex, less reliable and therefore technically inferior to Option 4.

4.2 Comparison on capital cost

The estimated costs of each the options in the long list are set out in Table 1 and Figure 12 below. For a full breakdown see Appendix 1-1 to 1-7.

Option	Transmission Cost (£m)	Distribution Cost (£m)	Total including contingency (10%) (£m)
Option 1 - Do nothing	-	-	-
Option 2 – Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and new Tullygoonigan - Richill 33 kV ring	10.90	10.82	23.90
Option 3 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and rebuild existing Tullygoonigan - Richill 33 kV circuit	10.90	8.05	20.85
Option 4 – Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits	23.15	3.60	29.43
Option 5 – Connection of a new Armagh Central BSP to Tandragee via one new monopole single 110 kV circuit	11.86	0.7	13.81
Option 6 – Connection of a new Armagh Central BSP to the proposed Turleenan 400/275 kV substation	54.88	3.45	64.16
Option 7 – Connection of a new Armagh Central BSP to the proposed Turleenan – Woodland 400 kV circuit	86.92	3.15	99.08
Option 8 - Connection of a new Armagh Central BSP to Tandragee via two new underground cable 110 kV circuits	55.86	2.37	64.04

Table 1 - Cost estimate for long list options

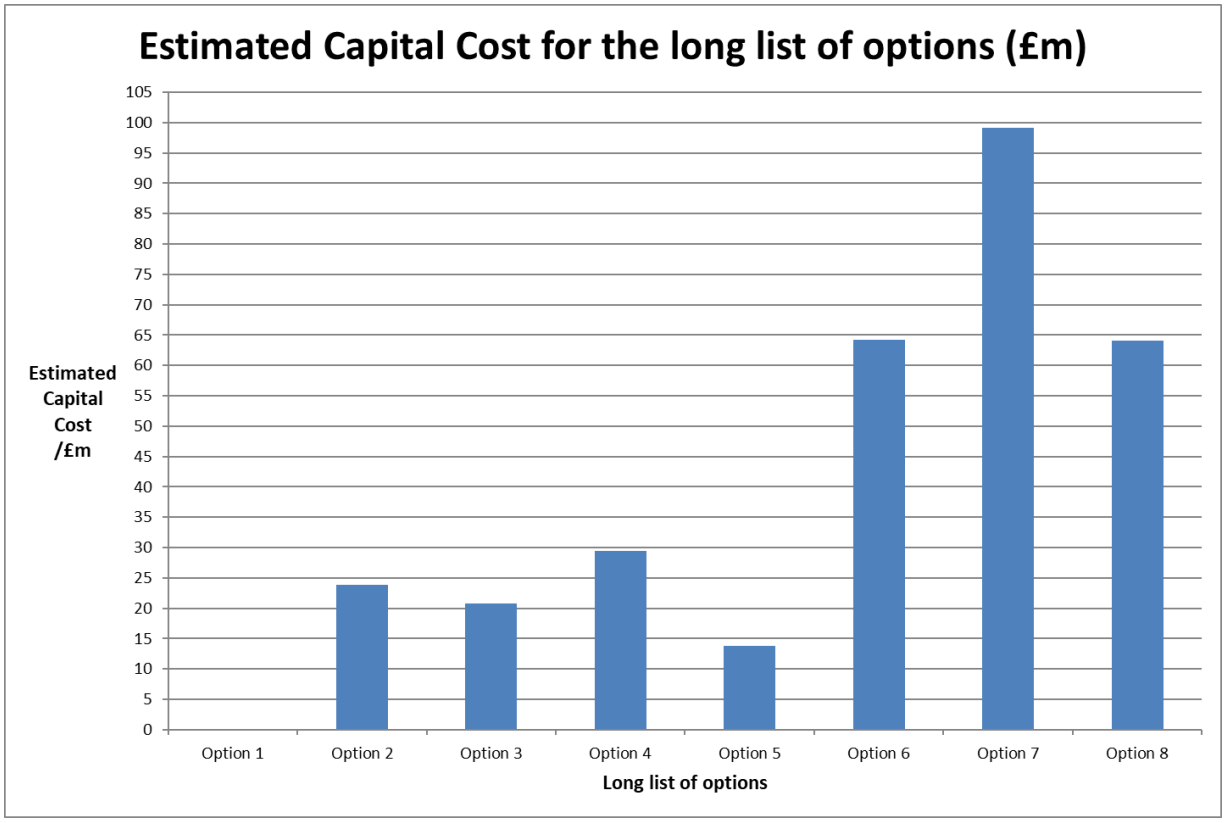

Figure 12 - Comparison of cost estimates for long list options (obtained from NIE Networks unit costs)

Options 2 and 3, based on separate 110 kV reinforcements at Drumnakelly and 33 kV reinforcement at Armagh, are narrowly the least cost options. This is because despite including for a new 110/33 kV substation they avoid the extensive 110 kV overhead line circuit construction required in Option 4.

Option 4 is almost 30% higher cost than Option 2 and 3 due to the need to construct two 110 kV overhead line circuit from Tandragee to Armagh Central.

Option 6 is based on utilising Turleenan substation (part of the proposed North - South Interconnector) to establish a 110 kV node, is more than twice the cost of Option 4 at £64m. Option 7 is the highest cost of option, over three times that of Option 4. Whilst it saves on the cost of 110 kV overhead line circuit lengths it requires extremely high value items to form a new 400/275/110 kV substation including switchgear and 400/275/110kV transformers. Option 7 is the most expensive option at £99m.

Finally, Option 8 involving 110 kV underground cable circuits is over twice the cost of Option 4 at £64m. This is because underground cable is more expensive that overhead line and because it needs reactive compensation.

4.3 Deliverability

An assessment of the deliverability of each option is provided below. This is based on information received from the feasibility investigations and from knowledge in completing other transmission and distribution projects.

The deliverability ranges from very good to very poor. For the graphic very poor deliverability would be designated a dark blue colour and very good deliverability would be designated a yellow colour. Table 2 and Table 4 in section 5.4 show how this representation is used in the long list of options comparison and the short list of options multi criteria assessment.

4.3.1 Option 1 – Do Nothing

This option does not involve any delivery.

4.3.2 Option 2 – Second Bulk Supply Point (BSP) at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and new Tullygoonigan Richill 33 kV ring

Option 2 requires a new 110/33 kV substation at Drumnakelly Main and some distribution works in the Armagh area. This option does not however involve the development of any 110 kV overhead line circuits which make it less challenging to deliver than Option 4. In fact, from a complexity perspective this option would be classed at Tier 2. However, it does involve a significant extent of 33 kV overhead lines.

By contrast Option 4 is a Tier 3 project as it involves approximately 36km of transmission voltage overhead line with a much greater number of receptors and landowners involved. That makes the delivery of this option significantly less complex than Option 4.

4.3.3 Option 3 – Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and rebuild existing Tullygoonigan Richill 33 kV circuit

Option 3 requires a new 110/33 kV substation at Drumnakelly Main and new 33 kV overhead lines in the Armagh area. Whilst option does not involve the development of any 110 kV overhead lines it does include a similar extent of 33 kV overhead line with similar design and landowner engagement requirements. As with Option 2 the delivery of this option is significantly less complex than Option 4.

4.3.4 Option 4 – Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits

Option 4 also involves the development of a new 110/33 kV substation. Unlike with Options 2 and 3 this is at an existing 33/11 kV site (Armagh Central). However crucially it also involves development of approximately 36km of 110 kV overhead line circuit. However, it does not require any 33kV overhead line. Therefore, deliverability is expected to be slightly more challenging relative to Options 2 and 3.

4.3.5 Option 5 – Connection of a new Armagh Central BSP to Tandragee via one new monopole single 110 kV circuit

Option 5 is very similar to but involves half the length of overhead line than Option 4. It is therefore more deliverable than Option 4.

4.3.6 Option 6 – Connection of a new Armagh Central BSP to the proposed Turleenan 400/275 kV substation

The 110 kV overhead line construction would be from Turleenan rather than Tandragee as in Option 4. The reason for including this option was to see if the line could be any shorter.

The use of 275/110 kV transformers are normally reserved for the establishment of a grid supply point (GSP) from which several bulk supply points would be supplied. For transformers of this type there would be more onerous supply chain issues including long lead times and potential for additional delays.

There would be cumulative visual impact with developing new 110 kV lines relatively close to the planned Turleenan - Woodland 400 kV circuit and Turleenan substation. However, the main feature of this option that makes it more complex to deliver would be extending the proposed Turleenan 400/275 kV substation to accommodate 275/110 kV transformers and a 110 kV double busbar. It is unlikely that a convincing case of need or assessment of alternatives could be made for that in the planning application and so this option is assessed to have a poor deliverability.

4.3.7 Option 7 – Connection of a new Armagh Central BSP to the proposed Turleenan – Woodland 400 kV circuit

The overwhelming feature of this option is the development of a new 400/275/110 kV substation. In this case it is unlikely that a convincing case of need or adequate

consideration of alternatives could be made in any planning submission or environmental statement. The planning application would therefore likely fail.

By developing a new substation along the route of the proposed Turleenan – Woodland 400 kV circuit this option would achieve a marginally shorter 110 kV route length than proposed in Option 4. However, it still requires the linear development of two 110 kV overhead line circuits of 12km each. Therefore, much like Options 4, 5 and 6 this would involve a considerable number of landowners and receptors.

For the above reasons, it would be least favourable.

4.3.8 Option 8 – Connection of a new Armagh Central BSP to Tandragee via two new underground cable 110 kV circuits

The key difference with this option compared to option 4 is that it proposes two underground cable circuits, approx. 20.5km each, instead of overhead line circuits. Due to it being an underground cable reactive compensation would be required at Tandragee which would involve a significant extension of the compound.

In general cable works do not require a planning application. However, as they are associated with the substation extension at Tandragee and Armagh Central it might be necessary that their route is included.

Whilst appearing to be out of site it's tempting to think that this might be more deliverable than an overhead line option. However, the cable route would involve considerable design and route investigation. The cable route would encounter many technical constraints, e.g. other utilities, watercourses, bridges etc. There may need to be diversions into private property. Therefore, this option is considered similar in terms of delivery to Option 4.

4.3.9 Visual Representation of Multi-criteria

Table 2 below provides a visual comparison of the long list of options based on the technical performance, deliverability in the required time frame and capital cost. SONI considers these criteria as important in rationalising the long list of options. An option with a very good performance is designated a yellow colour and an option with a very poor performance is designated a dark blue colour, as per the key in Table 2.

Additional criteria are used to appraise the short list of options including lifecycle (net present) costs over the asset's lifetime and environmental impact.

Key: Less favourable — More favourable

Option	Technical performance	Deliverability[3]	Cost of option (£m)[4]
Option 1 - Do nothing		N/A	N/A
Option 2 – Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and new Tullygoonigan Richill 33 kV ring			23.90
Option 3 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and rebuild existing Tullygoonigan Richill 33 kV circuit			20.85
Option 4 – Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits			29.43
Option 5 – Connection of a new Armagh Central BSP to Tandragee via a new monopole single 110 kV circuit			13.81
Option 6 – Connection of a new Armagh Central BSP to the proposed Turleenan 400/275 kV substation by establishing a Turleenan 110 kV substation			64.16
Option 7 – Connection of a new Armagh Central BSP to the proposed Turleenan – Woodland 400 kV circuit			99.08
Option 8 - Connection of a new Armagh Central BSP to Tandragee via two new underground cable 110 kV circuits			64.04

Table 2 - Comparison of options in long list

4.4 Rejection of options from long list

Based on the criteria shown in the previous section the following options have been rejected from the long list.

[3] Technical performance and Deliverability colour scale: very good – yellow; good – light green; medium – dark green; poor – blue; and very poor – dark blue.

[4] Cost of option (£m) colour scale: less than £20m – yellow; between £20m and £30m – light green; between £30m and £40m – dark green; between £40m and £65m – blue; and greater than £65m – dark blue.

4.4.1 Option 5 – Connection of a new Armagh Central BSP to Tandragee via one new monopole single 110 kV circuit:

Option 5 did not meet the voltage step change limits for normal switching operations on the transmission system (these were in excess of TSSPS limits). Additionally, voltage drops on the distribution system for the loss of the 110 kV circuit were found to also be in breach of limits.

Furthermore, the operation of a single transmission circuit in parallel with underlying distribution circuits is non-standard and results in a number of operational concerns. For example, in the event of a loss of both transformers at Drumnakelly, the demand blocks at Armagh and Drumnakelly would be supplied from Armagh Central. This would be very difficult to mitigate against. Therefore, this option is not shortlisted.

4.4.2 Option 6 - Connection of a new Armagh Central BSP to the proposed Turleenan 400/275 kV substation by establishing a Turleenan 110 kV substation

This option is significantly more expensive than other options in the longlist and given the need to divert around the city of Armagh there is no advantage to be gained from connecting to Turleenan as the new circuits would be of similar length to that which would be required from Tandragee or Drumnakelly.

From a technical perspective a connection to a 400 kV substation such as that proposed at Turleenan would be disproportionate use of those strategic assets for a local distribution system reinforcement. It would also require significant works at the proposed Turleenan substation including a land purchase, substation boundary extension, a 275 kV GIS switchboard extension (with additional 275 kV GIS circuit breakers) and the implementation of a 110 kV node through two 275/110 kV interbus transformers. From a deliverability perspective achieving consents to expand Turleenan for this option would be considered very poor.

Therefore, this option is not shortlisted.

4.4.3 Option 7 – Connection of a new Armagh Central BSP to the proposed Turleenan – Woodland 400 kV circuit

This option is more than three times the cost of Option 4 and by a large margin the most expensive at £99m.

If the connection to Armagh was teed onto the Turleenan – Woodland line, then for the loss of the proposed circuit supply to Armagh Central would also be lost. This would not be compliant with standards. If there was a switching station then Armagh Main could be supplied from either Turleenan in Northern Ireland or Woodland in Ireland. However in the scenario where this occurred during routine switching between the new Armagh Main 33 kV system and any other bulk supply point then a portion of the interconnector flows would be redirected through this parallel for which it is clearly not designed for. This would pose a completely unacceptable safety risk, for operational staff.

A new 400 kV substation would be a very significant and disproportionate development for a local issue. The extra high voltage switchgear and plant introduces complex design and procurement challenges into this option which are not normally associated with a local reinforcement. It could be challenging to procure the required plant and unlikely to obtain consents.

Therefore, this option is not shortlisted.

4.4.4 Option 8 – Connection of Armagh Central 110/33 kV to Tandragee via two new underground cable 110 kV circuits

Option 8 would operate similar to option 4 and provide long term security for the demand in the Armagh area (when all design challenges are addressed).

From a technical perspective the installation of two approx. 20.5km underground cable circuits would require reactive compensation due to the proportion of cable circuit and the impact this has on voltage control at Tandragee substation, particularly when the system is lightly loaded. A substation compound extension would be required to site the necessary shunt reactors.

Additionally, from a technical perspective, the concept of zero miss phenomena would affect both the energisation of the cable circuits and their associated shunt reactors. Mitigation measures would be required such as Point on Wave (POW) switching capabilities and/or Pre-Insertion Resistor (PIR). These technologies are also challenging to keep in operating condition over longer periods of time.

Cable circuits are also technically inferior because they have a lower availability than overhead line circuits. Whilst not subject to weather in the way an overhead line could be, cables are much more difficult to repair, with specialist jointing skills, involving

considerable outage times. In addition, standard practice is that cables share a dual trench. There is a risk that both circuits could be damaged, for example during horizontal directional drilling, as they would be mostly routed within the road network.

From a cost perspective this option is over twice the cost of Option 4. Therefore, this option is not shortlisted.

5 Preliminary appraisal of shortlisted options

5.1 Shortlisted options

The following options are shortlisted for further investigation:

- Option 1 - Do nothing;
- Option 2 – Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and new Tullygoonigan Richill 33 kV ring;
- Option 3 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and rebuild existing Tullygoonigan Richill 33 kV circuit; and
- Option 4 – Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits.

5.2 Lifecycle assessment

5.2.1 Option 1 - Do Nothing

VoLL analysis has been used to financially assess the impact of future potential faults, planned maintenance outages and normal system operation (NSO) on the 33 kV network supplying the Armagh area. This analysis uses load index data (and extrapolating out to 2050), historic outage information to determine a fault probability and maintenance probability (from 1992-2024 on the four 33 KV circuits supplying the Armagh area) and a VoLL figure of £22.22k/MWh (which is then updated based on the Harmonised Index of Consumer Prices (HICP)). The overall total cost of VoLL from faults, maintenance and during normal system operation from 2024-2064 is estimated to be £258.93m. The costs start from 2024 and increase incrementally until reaching a peak at the end of the appraisal in 2064.

5.2.2 Option 2 – Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and new Tullygoonigan - Richill 33 kV ring

This option would address the capacity issues expected at Drumnakelly into the future indefinitely. However, studies showed that, based on forecast demand growth associated with low carbon technologies the 33 kV reinforcements in Armagh would become non-compliant with voltage standards by 2033. Load shedding would be required to maintain compliance with the DSSPS. It would be extremely imprudent to implement a scheme that did not have sufficient capacity to support a single circuit outage on the 33 kV

system by the time it is installed and so the only way this scheme makes sense is if the forecast demand growth due to LCTs is overestimated.

A more prudent approach would be to begin preconstruction for the longer-term reinforcement well in advance so it would be in place shortly after Option 2. In this case if Option 4 is assumed as the next step, then the Option 2 assets in particular the second 110/33 kV substation at Drumnakelly Main is nugatory almost immediately.

Therefore, for the purposes of the lifecycle appraisal, the cost of Option 4 is assumed to be required almost immediately after Option 2, with the preconstruction beginning in 2033 and option 4 constructed as additional reinforcement in 2042.

The cost of VoLL also apply to this option and begin from 2024 and increases incrementally until the reinforcement is implemented in 2036.

5.2.3 Option 3 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and rebuild existing Tullygoonigan - Richill 33 kV circuit

Similar to Option 2, for the purposes of the lifecycle appraisal the capital cost of Option 4 is assumed to be progressed reasonably soon after Option 3, with preconstruction beginning in 2032 and option 4 constructed as additional reinforcement in 2041.

The cost of VoLL also apply to this option beginning from 2027 and increasing incrementally until the reinforcement is implemented in 2036.

5.2.4 Option 4 – Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits

Option 4 does not require any investment beyond its completion date of 2035 out to the end of the planning horizon.

The cost of VoLL would also apply to this option and begin from 2027 and increase incrementally until the reinforcement is implemented in 2035.

5.3 Environmental impact of the shortlisted options

RPS was asked to carry out a desktop environmental assessment of the shortlisted options based on the environmental constraints in the study area. For each of the options, several sample corridors were established for the new overhead line circuits,

within each of the main study areas. The least environmental corridor was determined, followed by two alternative corridors.

The RPS environmental constraints model uses a cell cost surface to represent the various environmental constraints that are associated with the study area. Each option was represented by a total number of cost cells which provide an overall cumulative constraint cost. Some of these cells which are more constrained will have a greater cost to cross. If an option has encountered many of these cells it will have received a high score representing many different constraints, some of which could impact of the deliverability of that option.

RPS carried out two assessments of the sample corridors. The first assessment used the full width of the corridors. This assessed every cell within the 500m corridor and cumulatively scored all the constraints encountered. The second assessment used a 100m centreline in the middle of the corridor. This assessed only the cost cells along the centreline. The results of these assessments are shown in Table 3 below.

These environmental scores are also set out in the multi criteria assessment in Table 4 of section 5.4 of this report. For this assessment the constraints within the 500m corridor only were used to present all the constraints within each corridor.

Option	**Range of lengths per Option (km)**	**RPS option environmental scores**
		Constraints within 500m OHL corridor
Option 1 - Do nothing	N/A	N/A
Option 2 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and new Tullygoonigan Richill 33 kV ring	48.7 – 54.3	533,497– 594,029
Option 3 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and rebuild existing Tullygoonigan Richill 33 kV circuit	37.3 – 41.2	316,456– 363,627
Option 4 - Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits	41.4 – 43.2	519,127 – 540,473

Table 3 - Constraint scoring of options by RPS

5.3.1 Visual impact - monopole vs twin wood pole

The shortlisted options all involve the construction of new overhead line, either at 33 kV or 110 kV. The requirements for each option are listed below.

- Option 2 involves the construction of approx. 33 km of 33 kV heavy structure (200 mm^2) circuits. It also involves the rebuilding of approx. 14km of existing 33 kV circuits to accommodate a larger conductor (200 mm^2), with these circuits positioned close to the existing alignments. Photographs of an existing heavy structure 33 kV circuit are provided in Figure 13.
- Option 3 also involves the construction of approximately 18 km of 33 kV heavy structure (200 mm^2) circuits and the rebuilding of approx. 14km of existing 33 kV circuits to accommodate a larger conductor (200 mm^2).
- Option 4 involves the construction of approx. 37 km of 110 kV overhead line. To minimise the visual impact and cost it is proposed that the design would be based on a predominantly monopole construction. This would be in preference to the more commonly used portal (twin wood pole) design. Photographs of existing monopole (located in Great Britain) and Portal circuits are shown in Figure 15 and Figure 15. For this option the proposal would be to use monopole construction for suspension (Figure 14) and steel towers at angles (Figure 15– R).

Figure 13 - 33 kV heavy construction circuit (200m^2) - suspension (L) and angle (R)

Figure 14 - 110 kV monopole trident overhead line circuit - suspension poleset

Figure 15 - 110 kV heavy portal (twin wood pole) overhead line circuit - suspension (L) and angle (R)

In summary if option 4 is chosen as the best performing option, it is recommended that a predominately monopole construction is used for the following reasons:

- It has a similar visual impact to the 33 kV heavy construction compared to a portal design;
- It is capable of carrying a conductor of more than sufficient rating for the Armagh area demand;
- Due to there being sufficient earthing arrangements at the existing Armagh Central substation, there is no need for a construction capable of carrying an earth wire; and
- Monopole is a more cost-effective construction method, with a per kilometre circuit cost being approx. 70% of the cost of a Portal circuit.

5.4 Multi-criteria assessment

Table 4 combines the technical performance, deliverability, capital cost, net present cost and environmental scoring for each of the reinforcement options. The best performing option is Option 4. For more details see Appendix 2.

Key: Less favourable  More favourable

Option	Technical Performance	Deliverability	Cost of option (£m)	Net Present Cost (£m)[5]	Environmental Appraisal
Option 1 - Do nothing		N/A	N/A	90.04	N/A
Option 2 – Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and new Tullygoonigan Richill 33 kV ring			23.90	47.40	
Option 3 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and rebuild existing Tullygoonigan Richill 33 kV circuit			20.85	45.05	
Option 4 – Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits			29.43	29.56	

Table 4 - Comparison of options

[5] Net present cost colour scale: less than £30m – yellow; between £30m and £40m – light green; between £40m and £60m – dark green; between £60m and £80m – blue; greater than £80m – dark blue.

6 Preliminary preferred option

Option 4 – Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits, is selected as preliminary preferred option. This option secures the load in the Armagh region in the long term, it delivers scope for future load growth in the area and can facilitate load transfers from the adjacent distribution network if required. It is the optimum solution when considering additional demand growth resulting from the decarbonisation of heat and transport.

This selection is based on a multi-criteria analysis of capital and lifecycle costs, technical merit, deliverability and environmental impact. Option 4 placed second in an environmental study completed on the options within the shortlist. From a deliverability perspective all three options are similar with new substation works and new overhead line circuits required, with Option 4 requiring new 110 kV overhead line circuits as opposed to 33 kV circuits in Options 2 and 3. Considering the capital costs, Option 4 is more expensive than Options 2 and 3, with a capital cost of £29.43 million. However, when considering the lifecycle costs of the shortlisted options, although initially the capital cost investment is higher, Option 4 is the least cost option from the Net Present Cost assessment at £29.56m. This is because Option 2 and Option 3 have shorter scheme lives and a follow up reinforcement would be required, depending on uptake of LCT.

Whilst Options 2 and 3 would massively improve the voltage and thermal issues on the 33 kV system, based on current LCT forecast by NIE Networks, there would already be instances where the system would fall outside of standard by the time they are energised. Option 4 is the realistic long term next step and would really need to be delivered within a reasonable period of time and depending of course on LCT uptake after Option 2 or 3.

Therefore, for the lifecycle assessment of Options 2 and 3, the capital cost of Option 4 as the next step is included in 2040/41. This results in a higher life cycle cost for these options.

It is therefore considered prudent to progress with Option 4 as preferred option to provide long term system security in the Armagh area.

For the purposes of our stakeholder consultation and TNPP submission this is selected as the preliminary preferred option.

7 Stakeholder engagement

SONI has carried out a high-level stakeholder engagement exercise with the local authorities affected by the project.

Newry and Armagh is the local parliamentary constituency that is affected by this project. Additionally, Armagh, Banbridge and Craigavon Borough Council is the relevant Council and local planning authority.

SONI has engaged with these local representatives and authorities to discuss the project.

Wider stakeholder engagement will be carried out in the latter parts of the SONI's Grid Development Process[6]. By then SONI and NIE Networks will have carried out investigations into the detailed design requirements of this project. Stakeholder engagement at this stage will help to inform the public of the project proposals and take on board any feedback to help finalise proposals.

7.1 Part 1 stakeholder engagement:

Table 5 collates the main stakeholders that SONI has engaged with for the 'Armagh Upgrade' project. In accordance with SONI's Grid Development Process this stakeholder engagement was commenced during Part 1 of project development.

The project area encompasses one council area and one Parliamentary Constituency. The project team has engaged with each area on separate basis at this stage of the project.

Parliamentary Constituency:	Council Area:
Newry and Armagh	Armagh, Banbridge and Craigavon

Table 5 - Part 1 Engagement

7.1.1 Stakeholder Engagement feedback:

SONI met with elected representatives and planning officials within the project study area along the route of the preliminary preferred option. This engagement took place virtually and SONI has also provided our Part 1 presentation to stakeholders as required.

[6] https://www.soni.ltd.uk/community/engaging-community

Feedback collated from the stakeholder engagement meetings was analysed and the emergence of eight key themes has been identified. The themes and extracts from the meetings with the stakeholders are outlined below.

In total, four individual stakeholders were consulted as part of the process; many elected representatives were contacted and offered briefings and we anticipate more meetings will arise following the submission of the TNPP and ahead of our transition to Part 2 of our process[7]. In Part 2 of our process for developing the Grid we identify the extent of any modifications. This will involve meeting with landowners to determine where we will locate any new terminal towers and cable easements. A more extensive public engagement exercise will be required in this part to help finalise our proposals in preparation for our planning application.

We have analysed the emerging key themes from our engagement; the frequency of the issues raised is outlined in Figure 16 below.

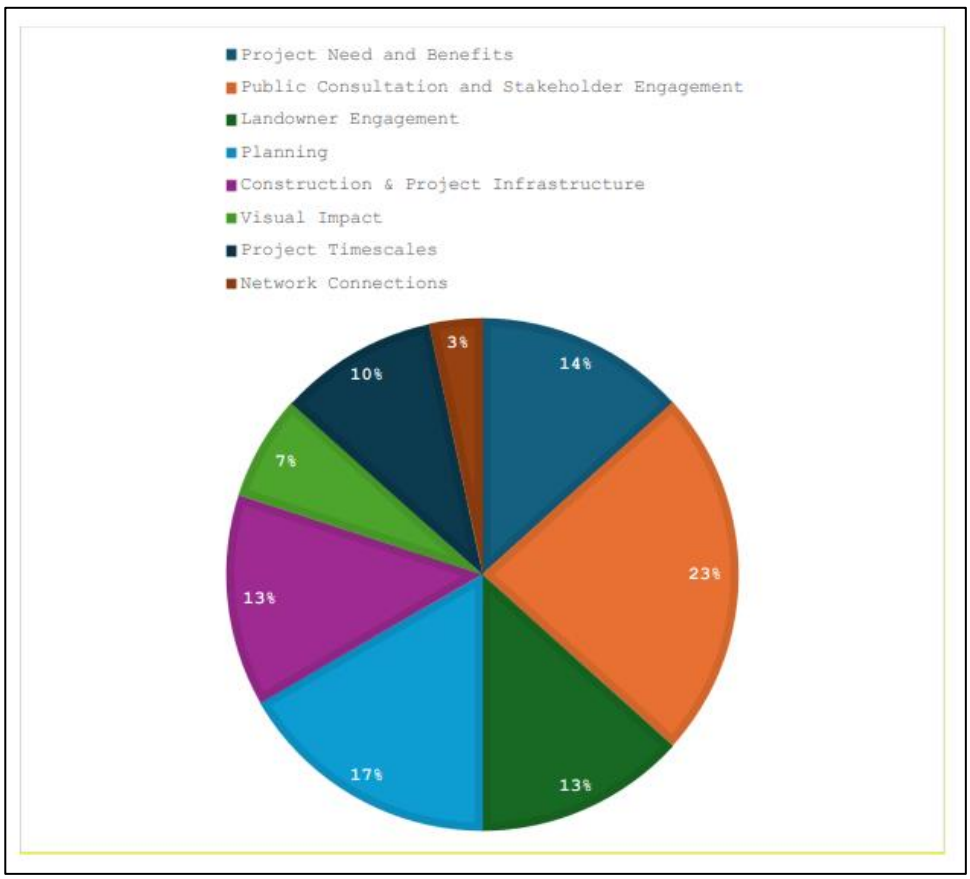

Figure 16 - Key feedback from Part 1 Stakeholder Engagement

[7] https://www.soni.ltd.uk/media/SONIs-Powering-The-Future-Grid-Development-Process-brochure.pdf

The majority of the feedback raised by stakeholders was in relation to any new infrastructure and early engagement with landowners. There was some positive feedback regarding the use of monopole overhead line construction to reduce the visual impact of the new 110 kV circuits between Armagh and Tandragee. There were some queries related to planning timescales, the disruption that underground cabling would have on the public in Armagh City and the benefits to people living along the route of the project.

8 Next steps

This Preliminary Preferred Option Report has been updated following stakeholder engagement with statutory consultees and elected representatives.

The report will be used as the basis for the preparation of the Transmission Network Pre-construction Project (TNPP) submission.

The next steps for the project will be as follows:

- Prepare and submit TNPP;
- Publish decision and accompanying reports on the SONI website;
- Upon approval of TNPP funding commence Part 1 governance steps; and
- Commence Part 2 of the SONI Grid Development Process.

9 Appendices

Appendix 1 - Estimated TO costs for each option

Option 2 - Second Bulk Supply Point (BSP) at Drumnakelly plus new Drumnakelly – Armagh 33kV circuit and new Tullygoonigan Richill 33kV ring

Transmission

Item Description	Unit cost	Number	Total (£m)
Substation works			
Pre-enabling new 110/33 kV substation	2.91	0.7	2.04
Pre-enabling for mesh extension	2.91	0.2	0.58
reposition terminal tower	1.00	1	1.00
110 kV mesh extension (including 1 new mesh circuit breaker)	1.22	1	1.22
110 kV mesh circuit breaker	0.76	1	0.76
110/33 kV control building	0.15	1	0.15
110/33 kV transformer	1.58	2	3.15
Protection costs	0.07	2	0.14
Cable works			
110 kV duplicate cable (100m lenghs) - for TXs to existing mesh	0.62	3	1.86

Sub-total	**10.90**
Contingency (10%)	**1.09**
Total	**12.00**

Distribution

Item	Unit cost	Number	Total
Substation works			
new 33 kV switchboard (16 panel)	1.72	1	1.72
Cable works			
33 kV cable connections to new switchboard (per 100m)	0.04	6	0.22
33 kV cable connections from new switchboard to new TXs (per 100m)	0.04	1	0.04
Overhead line works			
New 200mm^2 33 kV OHL circuit (Drumnakelly - Tullygoonigan)	0.15	15	2.26
New 200mm^2 33 kV OHL circuit (Drumnakelly - Armagh Central)	0.15	18.2	2.74
New 200mm^2 33 kV OHL circuit (rebuild)	0.16	14.1	2.29
Undercrossings - 33 kV	0.06	7	0.42
Undercrossings - 11 kV	0.03	38	1.14

Sub-total	**10.82**
Contingency	**1.08**
Total	**11.90**

Total Costs

Transmission	**12.00**
Distribution	**11.90**
Total	**23.90**

Figure A1-1- Option 2 cost estimate

Option 3 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and rebuild existing Tullygoonigan Richill 33 kV circuit

Transmission

Item Description	Unit cost	Number	Total (£m)
Substation works			
Pre-enabling new 110/33 kV substation	2.91	0.7	2.04
Pre-enabling for mesh extension	2.91	0.2	0.58
reposition terminal tower	1.00	1	1.00
110 kV mesh extension (including 1 new mesh circuit breaker)	1.22	1	1.22
110 kV mesh circuit breaker	0.76	1	0.76
110/33 kV control building	0.15	1	0.15
110/33 kV transformer	1.58	2	3.15
Protection costs	0.07	2	0.14
Cable works			
110 kV duplicate cable (100m lenghs) - for TXs to existing mesh	0.62	3	1.86

Sub-total	**10.90**
Contingency (10%)	**1.09**
Total	**12.00**

Distribution

Item	Unit cost	Number	Total
Substation works			
New 33 kV switchboard (16 panel)	1.72	1	1.72
Cable works			
33 kV cable connections to new switchboard (per 100m)	0.04	5	0.18
33 kV cable connections from new switchboard to new TXs (per 100m)	0.04	1	0.04
Overhead line works			
New 200mm^2 33 kV OHL circuit (Drumnakelly - Armagh Central)	0.15	18.2	2.74
New 200mm^2 33 kV OHL circuit (rebuild)	0.16	14.1	2.29
Undercrossings - 33 kV	0.06	3	0.18
Undercrossings - 11 kV	0.03	30	0.90

Sub-total	**8.05**
Contingency	**0.80**
Total	**8.85**

Total Costs

Transmission	**12.00**
Distribution	**8.85**
Total	**20.85**

Figure A1-2 - Option 3 cost estimate

Option 4 - Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits

Transmission

Item Description	Unit cost	Number	Total (£m)
Substation works			
Purchase land at Armagh Central	0.05	1	0.05
Pre-enabling and diversion of sterile zone at Tandragee	2.91	0.125	0.36
110 kV AIS double busbar bay (including breaker)	0.76	2	1.51
110/33 kV transformer	1.58	2	3.15
Protection costs	0.07	2	0.14
Overhead line works			
New 110 kV monopole overhead line circuit (per km)	0.30	36.7	11.07
Cable works			
110 kV cable (single) - substation entry - part of new 110 kV monopole circuits	1.29	1	1.29
110 kV cable (dual) - Tandragee - part of new 110 kV monopole circuits	2.23	2.5	5.58

Sub-total	**23.15**
Contingency (10%)	**2.32**
Total	**25.47**

Distribution

Item	Unit cost	Number	Total
Substation works			
auto-changeover scheme	0.08	2	0.16
Cable works			
33 kV cable connections to new switchboard (per 100m)	0.04	2	0.07
33 kV cable connections from switchboard to new TXs (per 100m)	0.04	1	0.04
New 33 kV underground cable circuit (Armagh Central - Armagh North)	0.37	5.7	2.10
Overhead line works			
Undercrossings - 33 kV	0.06	5	0.30
Undercrossings - 11 kV	0.03	31	0.93

Sub-total	**3.60**
Contingency	**0.36**
Total	**3.96**

Total Costs

Transmission	**25.47**
Distribution	**3.96**
Total	**29.43**

Figure A1-3 - Option 4 cost estimate

Option 5 - Connection of a new Armagh Central BSP to Tandragee via one new monopole single 110 kV circuit

Transmission

Item Description	Unit cost	Number	Total (£m)
Substation works			
Purchase land at Armagh Central	0.05	1	0.05
110 kV AIS double busbar bay (including breaker)	0.76	1	0.76
110/33 kV transformer	1.58	1	1.58
Protection costs	0.07	1	0.07
Overhead line works			
New 110 kV monopole overhead line circuit (per km)	0.30	18.35	5.53
Cable works			
110 kV cable (single) - substation entry - part of new 110 kV monopole circuits	1.29	3	3.87

Sub-total	**11.86**
Contingency (10%)	**1.19**
Total	**13.04**

Distribution

Item	Unit cost	Number	Total
Cable works			
33 kV cable connections from switchboard to new TXs (per 100m)	0.04	1	0.04
Overhead line works			
Undercrossings - 33 kV	0.06	2	0.12
Undercrossings - 11 kV	0.03	18	0.54

Sub-total	**0.70**
Contingency	**0.07**
Total	**0.77**

Total Costs

Transmission	**13.04**
Distribution	**0.77**
Total	**13.81**

Figure A1-4 - Option 5 cost estimate

Option 6 - Connection of a new Armagh Central BSP to the proposed Turleenan 400/275 kV substation

Transmission

Item Description	Unit cost	Number	Total (£m)
Substation works			
Purchase land at Armagh Central	0.05	1	0.05
New 110/33 kV transformer	1.58	2	3.15
Protection costs at Armagh	0.07	2	0.14
Pre-enabling costs at Turleenan (110 kV and part for 275 kV GIS extension)	2.91	1	2.91
Purchase land at/near Turleenan	0.50	1	0.50
New 275/110 kV transformer	5.51	2	11.03
275 kV cabling (IBTX) - per 100m	0.72	4	2.88
110 kV cabling (IBTX) - per 100m	0.15	4	0.60
275 kV GIS double busbar bay circuit breakers (2 IBTXs, 1 bus coupler - includes extension works)	2.84	3	8.51
110 kV AIS double busbar bay circuit breakers (2 IBTXs, 2 circuits, 1 bus coupler)	0.76	5	3.79
110 kV control room	0.15	1	0.15
Protection costs at Turleenan - 275 kV	0.15	3	0.45
Protection costs at Turleenan - 110 kV	0.07	5	0.35
Overhead line works			
New 110 kV monopole overhead line circuit (per km)	0.30	38	11.46
Cable works			
110 kV cable (dual) - Armagh city - part of new 110 kV monopole circuits	2.23	4	8.92

Sub-total	**54.88**
Contingency (10%)	**5.49**
Total	**60.37**

Distribution

Item	Unit cost	Number	Total
Substation works			
auto-changeover scheme	0.08	2	0.16
Cable works			
33 kV cable connections to new switchboard (per 100m)	0.04	2	0.07
33 kV cable connections from switchboard to new TXs (per 100m)	0.04	1	0.04
New 33 kV underground cable circuit (Armagh Central - Armagh North)	0.37	5.7	2.10
Overhead line works			
Undercrossings - 33 kV	0.06	4	0.24
Undercrossings - 11 kV	0.03	28	0.84

Sub-total	**3.45**
Contingency	**0.34**
Total	**3.79**

Total Costs

Transmission	**60.37**
Distribution	**3.79**
Total	**64.16**

Figure A1-5 - Option 6 cost estimate

Option 7 - Connection of a new Armagh Central BSP to the proposed Turleenan – Woodland 400 kV circuit

Transmission

Item Description	Unit cost	Number	Total (£m)
Substation works			
Purchase land at Armagh Central	0.05	1	0.05
New 110/33 kV transformer	1.58	2	3.15
Protection costs at Armagh	0.07	2	0.14
Pre-enabling costs at new site along 400 kV circuit (400, 275 kV and 110 kV)	6.14	2	12.28
Purchase land at/near Turleenan - Woodland 400 kV circuit	0.50	1	0.50
New 400/275 kV transformer	8.27	2	16.54
New 275/110 kV transformer	5.51	2	11.03
400 kV cabling (IBTX) - per 100m	1.08	4	4.32
275 kV cabling (IBTX) - per 100m	0.72	4	2.88
110 kV cabling (IBTX) - per 100m	0.15	4	0.60
400 kV AIS double busbar bay circuit breakers (2 IBTX, 1 bus coupler, 2 circuits)	2.73	5	13.65
275 kV AIS double busbar bay circuit breakers (2 IBTX, 1 bus coupler)	1.82	3	5.46
110 kV AIS double busbar bay circuit breakers (2 IBTX, 2 circuits, 1 bus coupler)	0.76	5	3.79
400 kV control room	0.30	1	0.30
275 kV control room	0.23	1	0.23
110 kV control room	0.15	1	0.15
Protection costs at new site near 400 kV circuit - 400 kV	0.23	5	1.13
Protection costs at new site near 400 kV circuit - 275 kV	0.15	3	0.45
Protection costs at new site near 400 kV circuit - 110 kV	0.07	5	0.35
Overhead line works			
New 110 kV monopole overhead line circuit (per km)	0.30	24.4	7.36
Cable works			
110 kV cable (single) - substation entry - part of new 110 kV monopole circuits	1.29	2	2.58

Sub-total	**86.92**
Contingency (10%)	**8.69**
Total	**95.615**

Distribution

Item	Unit cost	Number	Total
Substation works			
auto-changeover scheme	0.08	2	0.16
Cable works			
33 kV cable connections to new switchboard (per 100m)	0.04	2	0.07
33 kV cable connections from switchboard to new TXs (per 100m)	0.04	1	0.04
New 33 kV underground cable circuit (Armagh Central - Armagh North)	0.37	5.7	2.10
Overhead line works			
Undercrossings - 33 kV	0.06	4	0.24
Undercrossings - 11 kV	0.03	18	0.54

Sub-total	**3.15**
Contingency	**0.31**
Total	**3.462**

Total Costs

Transmission	**95.62**
Distribution	**3.46**
Total	**99.08**

Figure A1-6 - Option 7 cost estimate

Option 8 - Connection of a new Armagh Central BSP to Tandragee via two new underground cable 110 kV circuits

Transmission

Item Description	Unit cost	Number	Total (£m)
Substation works			
Purchase land at Armagh Central	0.05	1	0.05
Pre-enabling and diversion of sterile zone at Tandragee	2.91	0.125	0.36
110 kV AIS double busbar bay (including breaker)	0.76	2	1.51
110/33 kV transformer	1.58	2	3.15
Protection costs	0.07	2	0.14
Purchase land for shunt reactors and compound extension	0.25	1	0.25
Pre-enabling and diversion of sterile zone for new shunt reactor compound	2.91	0.25	0.73
Shunt reactor (30 Mvar)	1.64	2	3.28
Cable works			
110 kV cable - shunt reactors teed connections to A and B circuits	0.33	2	0.66
110 kV cable (dual) - A and B circuits	2.23	20.5	45.72

Sub-total	**55.86**
Contingency (10%)	**5.59**
Total	**61.44**

Distribution

Item	Unit cost	Number	Total
Substation works			
auto-changeover scheme	0.08	2	0.16
Cable works			
33 kV cable connections to new switchboard (per 100m)	0.04	2	0.07
33 kV cable connections from switchboard to new TXs (per 100m)	0.04	1	0.04
New 33 kV underground cable circuit (Armagh Central - Armagh North)	0.37	5.7	2.10

Sub-total	**2.37**
Contingency	**0.24**
Total	**2.60**

Total Costs

Transmission	**61.44**
Distribution	**2.60**
Total	**64.04**

Figure A1-7 - Option 8 cost estimate

Appendix 2 - Net Present Cost Assessment and Assumptions

Assumption	Option			
	Option 1	*Option 2*	*Option 3*	*Option 4*
Capital Cost of Assets / Value of loss of Load	£90.04m[8]	£23.90m Further reinforcement capital cost of £29.43m in 2041/42	£20.85m Further reinforcement capital cost of £29.43m in 2040/41	£29.43m
Duration of construction	-	2 years, starting in 2034 Future works approx. 2 years starting in 2041	2 years, starting in 2034 Future works approx. 2 years starting in 2040	2 years, starting in 2034
Estimated Completion Date and Energisation	-	2035 Future works 2042	2035 Future works 2041	2035
Estimated TSO costs	-	£4.78m Approx. £3.76m for future works	£4.17m Approx. £3.76m for future works	£3.76m

[8] Value of Lost Load (VoLL) analysis has been completed using load index data of the Armagh Area 33 kV system, historic data on outages and maintenance duration for the four circuits and other assumptions. This has determined that without reinforcement the overall total cost of VoLL from faults, maintenance and during normal system operation from 2024-2064 is estimated to be £258.93m. Inputting these values into the net present value spreadsheet, and accounting for the discount rate, this brings the net present cost of Option 1 – do nothing to £90.04m.

Operation and Maintenance (Based on 1.3% capital value)	-	£320-350k £740k after future works (2042)	£280-310k £690k after future works (2041)	£380k
TOTAL NET PRESENT COST	£90.04m	£47.40m	£45.05m	£29.56m

Option key:

- Option 1 - Do nothing;
- Option 2 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and new Tullygoonigan Richill 33 kV ring;
- Option 3 - Second BSP at Drumnakelly plus new Drumnakelly – Armagh 33 kV circuit and rebuild existing Tullygoonigan Richill 33 kV circuit; and
- Option 4 - Connection of a new Armagh Central BSP to Tandragee via two new monopole single 110 kV circuits.