Laois-Kilkenny Reinforcement Project

Technical Comparison of AIS v GIS Substation Options

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1 Introduction

The purpose of the following report is to provide a cost and technical comparison between Air Insulated Switchgear (AIS) and Gas Insulated Switchgear (GIS) substations for the purposes of building a 400kV Substation for the Laois-Kilkenny Reinforcement Project.

The following was compared for both AIS and GIS:

- Double 400kV Busbar and Double 110kV Busbar

Technically, both AIS and GIS substation types are considered acceptable for the requirements of the Laois-Kilkenny Reinforcement Project.

1.1 Scope of Work

The scope of work of the Laois-Kilkenny Reinforcement Project is to develop a new 400/110 kV substation and associated 110kV circuit in order to reinforce the general areas of Kilkenny, Laois, Carlow and Kildare by way of improving quality of supply and security of supply.

The required transmission reinforcement involves construction of a new 400/110kV substation near Portlaoise, County Laois. The new substation will be looped into the existing Dunstown - Moneypoint 400kV overhead line and the existing Carlow - Portlaoise 110kV overhead line.

Construction of the new 400kV substation near Portlaoise, County Laois will be required to allow sufficient space to cater for the following development;

- Minimum 6 x 400kV bays (2 x Transformers, Moneypoint and Dunstown and two spare bays)
- 1 x 400kV double busbar (rated to 3000A)
- 1 x 400kV Coupler
- 2 x 400/110kV 250MVA double wound Transformers
- 1 x 110kV double busbar (rated to 2500A)
- 2 x 110kV Coupler (one of which is to be a spare)
- Minimum 9 x 110kV bays (2 x Transformers, Portlaoise, Athy, Ballyragget and four spare bays)

It is Eirgrid policy to provide a substation to cater for the current electrical needs of a region with capacity to cater for future needs of the region if required.

1.1.1 Proposed Development

For this specific project, to address the immediate requirements of the region, the station needs to be equipped with the following:

- A Double 400kV Busbar
- 2 x 400kV Line Bays (Moneypoint and Dunstown)
- 2 x 400kV/110kV Transformer Bays
- 1 x 400kV Coupler Bay
- A Double 110kV Busbar

- 3 x 110kV Line Bays (Portlaoise, Carlow and Ballyragget)
- 1 x 110kV Coupler Bay

1.1.2 Future Development

As noted above it is Eirgrid policy to provide a substation to cater for the current electrical needs of a region with capacity to cater for future needs of the region if required. To cater for this the following civil works are also included in the proposed substation design:

- 2 Future 400kV Line Bays
- 4 Future 110kV Line Bays
- 1 Future 110kV Coupler Bay

2 Substation Types Description

2.1 AIS Substation Description

An Air Insulated Switchgear substation (AIS substation) uses atmospheric air as the phase to ground insulation for the switchgear of an electrical substation.

The main advantage of the AIS substation is the scope of the substation for future offloading, for this reason AIS substations tend to be the most popular 400kV substation type. The equipment of an AIS substation is easily sourced and has a short lead-time; this means that the required future offloading does not need to be built immediately, unlike GIS where it must be considered.

The main disadvantage to the AIS substation is its overall size. At 400kV level these substations can have a significant footprint and require sensitive locating in any rural environment.

AIS are usually installed outdoor.

2.2 GIS Substation Description

A Gas Insulated Switchgear substation (GIS substation) uses Sulfur hexafluoride gas (SF6 Gas) whose dielectric strength is higher than air, to provide the phase to ground insulation for the switchgear of an electrical substation. This works where by the conductors and contacts are insulated by pressurised SF6 gas meaning clearances required are smaller than that of AIS substations.

The main advantage of the GIS substation is that this phase to phase spacing can be reduced significantly resulting in a substation with comparable load capability to an AIS substation but with a much smaller compound footprint. This is particularly advantageous in an urban environment where land size is at a premium. It also results in a smaller visual impact on a landscape as it can result in a significantly smaller footprint than its AIS counterpart.

The main disadvantage of the GIS substation type is the reduction in scope of the substation for future offloading, as equipment can be costly and difficult to source over the long term. However, with much more installations of GIS substations around the world, more standardisation has been introduced into manufacturing of the GIS equipment and therefore sourcing of any such required equipment has become less onerous and costly.

As a rule GIS are installed indoor. However outdoor GIS have also been installed in the recent past and are becoming a more common option.

3 GIS and AIS Substation Sizes

3.1 AIS Substation Size

Based on the single line diagrams given in Appendix B the minimum size of an AIS substation for this project would be as follows:

- Overall substation Compound Size 46,864.5m^2 (235.5m x 199m or approximately 11.6 acres)
- Height of highest element of substation ~ 28m (lightning protection structures situated in the substation compound)

Note: The switchgear in an AIS substation is outdoors therefore no building sizes are considered.

3.2 GIS Substation Size

Based on the single line diagrams given in Appendix B the GIS substation and building sizes for this project would be as follows:

- Size of 400kV Building 522.45m^2 (12.15m x 43 m)
- Size of 110kV Building 270m^2 (27m x 10m)
- Height of 400kV Building is ~11m.
- Height of the 110kV Building is ~8m.
- Height of highest element of substation ~ 28m (lightning protection structures situated in the substation compound)
- Overall Compound Size 10,612m^2 (90.7m x 117m or approximately 2.6 acres)

Assumptions:

A number of assumptions are taken into consideration with regards to the layout of the GIS substation. These are as follows:

- OHL connection (400kV) onto gantries with busbar connection (AIS to GIS) within compound
- Cable connection to substation at 110kV from line/cable interface masts located just outside compound

4 Maintenance & Operational Flexibility

Like any electrical equipment AIS and GIS switchgear requires continuous maintenance to prolong the life of the equipment. The maintenance of both AIS and GIS switchgear are subject to EirGrid's maintenance policy[1].

The annual service cost on both AIS and GIS are identical and the costs only vary when the switchgear is given a detailed service after 20-24 years, where this will need the manufacturer's assistance.

The maintenance costs used to compare the technologies in this report are based on the CER Costs which adhere to *EirGrid Transmission Maintenance Policy 50 years lifetime maintenance* (see Appendix D).

4.1 AIS Maintenance Requirements

- Ongoing maintenance requirements, all equipment exposed to weather conditions
- Disconnect contacts must be cleaned regularly, operating mechanisms must be checked and maintained

4.2 GIS Maintenance Requirements

- Arrangement of switchgear will play a significant role in how maintenance will be carried out
- Considerable dismantling may be required if a main element fails
- Manufacturer supervision will be required for the 20 year full overhaul

4.3 AIS v GIS – Operational Flexibility

4.3.1 AIS

- ESB AIS bays are laid out so no restrictions apply on adjoining bays during maintenance of any element of switchgear (Circuit Breaker, Current Transformer, Voltage Transformer, etc.)
- Maintenance of busbar disconnect - outage of relevant A or B busbar section

4.3.2 GIS

- GIS substations are purposefully compact to reduce overall compound required space. In a single busbar GIS substation, restrictions may be imposed on adjoining bays due to proximity or possibly gas compartment layout. The gas compartment layout will not impact on this substation as both 400kV & 110kV substations are double busbar. However the manufacturer's proposed maintenance method will be subject to approval.

[1] 'Transmission Asset Maintenance Policy', TAM-AMP-2008-I01, Version 1, April 2008.

5 Substation Capital Costs

As part of this comparison study a high level cost analysis was carried out. The analysis is high level as a detailed site specific design has not been identified. Taking this into consideration the following details are noted:

- The common costs for both AIS and GIS options are the HV power transformers, protection, professional fees, design fees and other miscellaneous items.
- The costs under comparison are the civil, HV equipment provision and installation.
- The detailed design may have an impact on the compound size due to the possible inclusion of lightning protection, etc.
- The common elements of the site development, which have no impact on the overall compound size, are the control room, transformer bunds and miscellaneous items such as access roadways.
- Material costs are based on either the internal ESBI database of term contract materials or manufacturer's costs for a specific project These costs are dependant on all materials being purchased at the same time and may vary from manufacturer to manufacturer[2].

The cost comparison between the AIS and GIS type substations is based on the details given in tables located in Appendix A [3]. These costs are 2010 costs.

5.1 Substation Land Acquisition Costs

Land value in the region was established by contacting local agents in mid 2010. It was then established that maximum value of agricultural land in that region was €10k per acre and small sites of circa 5 acres with road frontage were probably worth in the region of €75k. Based on these values and using the minimum footprints of the two substations which include the necessary station compound while excluding any road access and potential landscaping / screening areas, the following is the minimum that can be expected to pay for the different sites.

- AIS circa 11.6 acres = €116,000
- GIS circa 2.6 acres = €26,000

It should be noted that these figures are minimum figures and sites have been purchased in the past at multiples of the actual agricultural value after negotiations with the landowners.

[2] These costs excludes line or cable interfaces required to connect this substation to the ESB Transmission Network

[3] The material costs were taken from an internal ESBI database of term contract materials or directly from quotation from manufacturer where no such term contract exists. The maintenance costs are based on CER values derived from EirGrid maintenance policy. As this is the first 400/110kV Substation to be built onto the ESB Network the CER standard transmission charges could not be used as an estimating tool. The costs exclude line or cable interfaces into the 400kV & 110kV switchgear. The CER information can be seen at www.cer.ie/en/electricity-transmission-network-decision-documents.aspx?article=7ab5d769-38ba-450c-b772-74751011d83e

5.2 AIS HV Equipment Costs

The following costs are for the AIS option:

- Civil Construction Costs **€3,845,000**[4]
- Site Purchase and access roadways to be considered. For the purpose of this report (based on recent agricultural land purchases in the region) the site purchase for the AIS option has been estimated at **€116,000**
- Variations will apply dependant on site conditions

5.2.1 Double 400kV Busbar & Double 110kV Busbar

Based on the Single Line Diagram for AIS application PE493-D108-005-001-000 which is contained in Appendix B. The total cost for provision and installation of AIS HV equipment and steelwork is **€6,513,480.**

5.3 GIS HV Equipment Costs

The following costs are for the GIS option:

- Civil Construction Costs are ~ **€2,425,000** [5](Exclusions are detailed in Appendix C)
- Site Purchase (access roadways not included) ~ **€26,000**
- Transformer Cable Costs are **~ €175,000**

5.3.1 Double 400kV Busbar & Double 110kV Busbar

Based on the Single Line Diagram for GIS application PE493-D108-005-002-001 which is contained in Appendix B:

- 400kV Provision[6] €4,950,000
- 110kV Provision €1,287,000
- Supervision & Installation €365,625

The total cost for provision and installation of GIS HV equipment and steelwork is **€6,602,625.**

5.4 AIS v GIS HV Equipment Cost Comparison

The following tables have been compiled for cost comparison purposes.

Table 5.1 shows the costs for the substation development. Only the costs associated with switchgear materials, installation and maintenance are included for comparison in these tables.

[4] These figures are based on a pro-rata for the most recent tender received (Lodgewood 220kV Station).

[5] These figures are based on a pro-rata for the most recent tender received (Lodgewood 220kV Station).

[6] Provision refers to total cost of construction

Comparison Summary	Cost
AIS Double Busbar	€12,284,470
GIS Double Busbar	€13,715,855

Table 5.1: Development costs associated with switchgear materials, installation and maintenance only (Ratio GIS : AIS = 1:0.9)

Table 5.2 shows the costs for the substation development. However, in association with switchgear materials, installation and maintenance costs; the comparison has been extended to include civil and common costs also.

Comparison Summary	Cost
AIS Double Busbar	€25,288,970
GIS Double Busbar	€25,385,355

Table 5.2: Development costs including civil & common costs in addition to costs associated with switchgear materials, installation and maintenance (Ratio GIS : AIS = 1:0.996)

5.5 Maintenance Costs

The maintenance costs used in this report are based on the CER Costs which adhere to EirGrid Transmission Maintenance Policy. 50 years lifetime maintenance has been used to compare the technologies. The maintenance comparison is shown in Table 5.3 shown below. Table 5.3 shows the development costs minus the maintenance costs.

Type of Switchgear	50 year cost
AIS Double Busbar	€5,770,990
GIS Double Busbar	€7,113,230

Table 5.3: Maintenance Costs (Ratio GIS : AIS = 1: 0.8)

Comparison Summary	Cost
AIS Double Busbar	€19,517,980
GIS Double Busbar	€18,272,125

Table 5.4: Development costs including civil & common costs in addition to costs associated with switchgear materials, installation minus maintenance costs (Ratio GIS : AIS = 1: 1.07)

6 Conclusion and Recommendations

This report compares the cost, size and maintenance & operational flexibility of Air Insulated Switchgear (AIS) and Gas Insulated Switchgear (GIS) type 400/110kV substations. The following are its conclusions.

6.1 Cost

Budget high level cost estimates show that the ratio of GIS to AIS cost is 1:0.9, with only the comparison of switchgear materials, installation & maintenance included. When the comparison is extended to civil, land & common costs, the ratio of GIS to AIS cost is 1:0.996. When the maintenance costs are subtracted the ratio of GIS versus AIS cost is 1:1.07.

The total estimated cost of the GIS option is €25,385,335 and for the AIS option it is €25,288,970.

6.2 Size

The minimum land take required for an AIS substation is 4 to 5 times more than the minimum land take for a GIS substation.

The estimated size of the GIS compound is 2.6 acres and of the AIS compound is 11.6 acres.

6.3 Maintenance & Operational Flexibility

AIS offers more scope for easier maintenance with GIS currently having long term maintenance (after 20 yrs) restricted to servicing by the original supplier. AIS also offers more scope in terms of operational flexibility due to the larger compound resulting in greater space available for change if required.

6.4 Recommendation

This report recommends the use of GIS technology for the 400/110 kV substation required as part of the Laois-Kilkenny Reinforcement Project. This recommendation is based on the reduced size of a GIS compound and also lower overall estimated development cost.

The smaller size offers more scope for selecting sites and the costs are similar to an AIS substation, a smaller size compound is also likely to have less impact on the receiving environment. The total estimated costs for the two substations are very similar with just under €100k difference in price (GIS being the more expensive – see table 5.2), however this is based on minimum land value so higher site prices could lead to a GIS substation being the less expensive option.

The maintenance of a GIS substation under the current proposals turns out more expensive (ratio of GIS : AIS = 1: 0.8), however it is envisaged that with the continuing developments in this technology the maintenance costs will come into line with the AIS maintenance costs over the next 20 years.

7 Appendices

Appendix A - High Level Costing[7]

Table A: AIS Double 400kV Busbar & Double 110kV Busbar

Substation Element	Quantity	Unit Cost	Total Cost
400kV line bay (double busbar)	2	€695,200	€1,390,400
400kV trafo bay (double busbar)	2	€714,000	€1,428,000
400kV coupler bay (double busbar)	1	€608,000	€608,000
400kV double busbar	1	€672,000	€672,000
400kV Installation			€840,000
110kV line bay (double busbar)	3	€150,000	€450,000
110kV trafo bay (double busbar)	2	€102,090	€204,180
110kV coupler bay (double busbar)	1	€90,400	€90,400
110kV double busbar	1	€60,000	€60,000
110kV Installation			€770,500
Switchgear Total			**€6,513,480**
Maintenance Total			**€5,770,990**
Switchgear plus 50 year maintenance Total			**€12,284,470**
Civil			€3,845,000
Land Costs			€116,000
Total including Site Development			**€16,245,470**
Transformer Cost	2	€3,400,000	€6,800,000
Control & Protection Cost			€1,443,500
Telecoms Estimate			€800,000
Total including available common costs			**€25,288,970**

[7] The material costs were taken from an internal ESBI database of term contract materials or directly from quotation from manufacturer where no such term contract exists. The maintenance costs are based on CER values derived from EirGrid maintenance policy. As this is the first 400kV Substation to be built onto the ESB Network the CER standard transmission charges could not be used as an estimating tool. The costs exclude line or cable interfaces into the 400kV & 110kV switchgear.

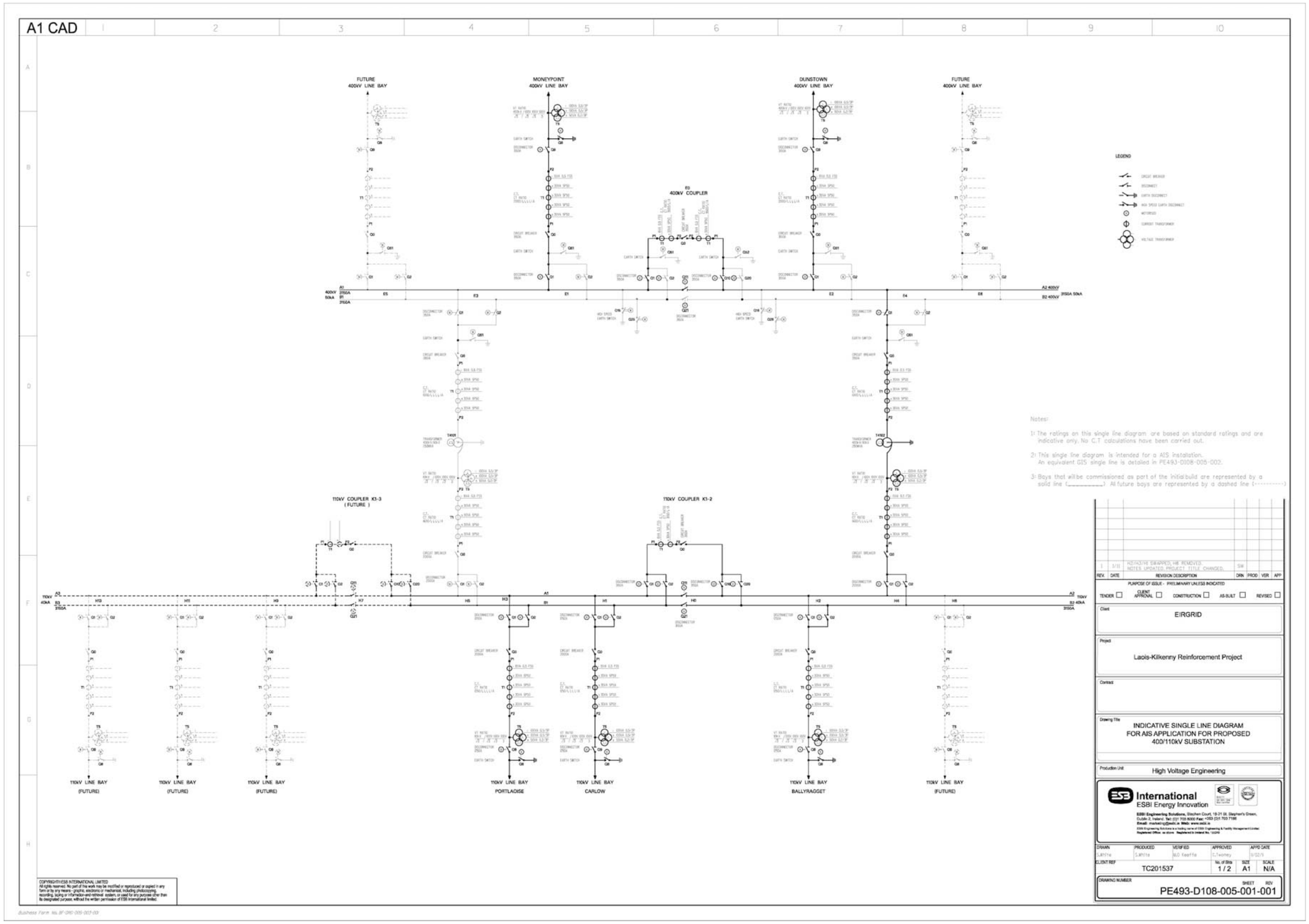
Table B: GIS Double 400kV Busbar & Double 110kV Busbar

Substation Element	Quantity	Unit Cost	Total Cost
400kV line bay (double busbar)	2		
400kV trafo bay (double busbar)	2		
400kV coupler bay (double busbar)	1		
400kV Total			€4,950,000
110kV line bay (double busbar)	4**		
110kV trafo bay (double busbar)	2		
110kV coupler bay (double busbar)	1		
110kV Total			€1,287,000
Installation	12		€265,625
Supervision	12		€100,000
Switchgear Total			**€6,602,625**
Maintenance Total			**€7,113,230**
Switchgear plus 50 year maintenance Total			**€13,715,855**
Trafo cables	2	€87,500	€175,000
Civil			€2,425,000
Land Costs			€26,000
Total including site development			**€16,341,855**
Transformer Cost	2	€3,400,000	€6,800,000
Control & Protection Cost			€1,443,500
Telecoms Estimate			€800,000
Total including available common costs			€25,385,355

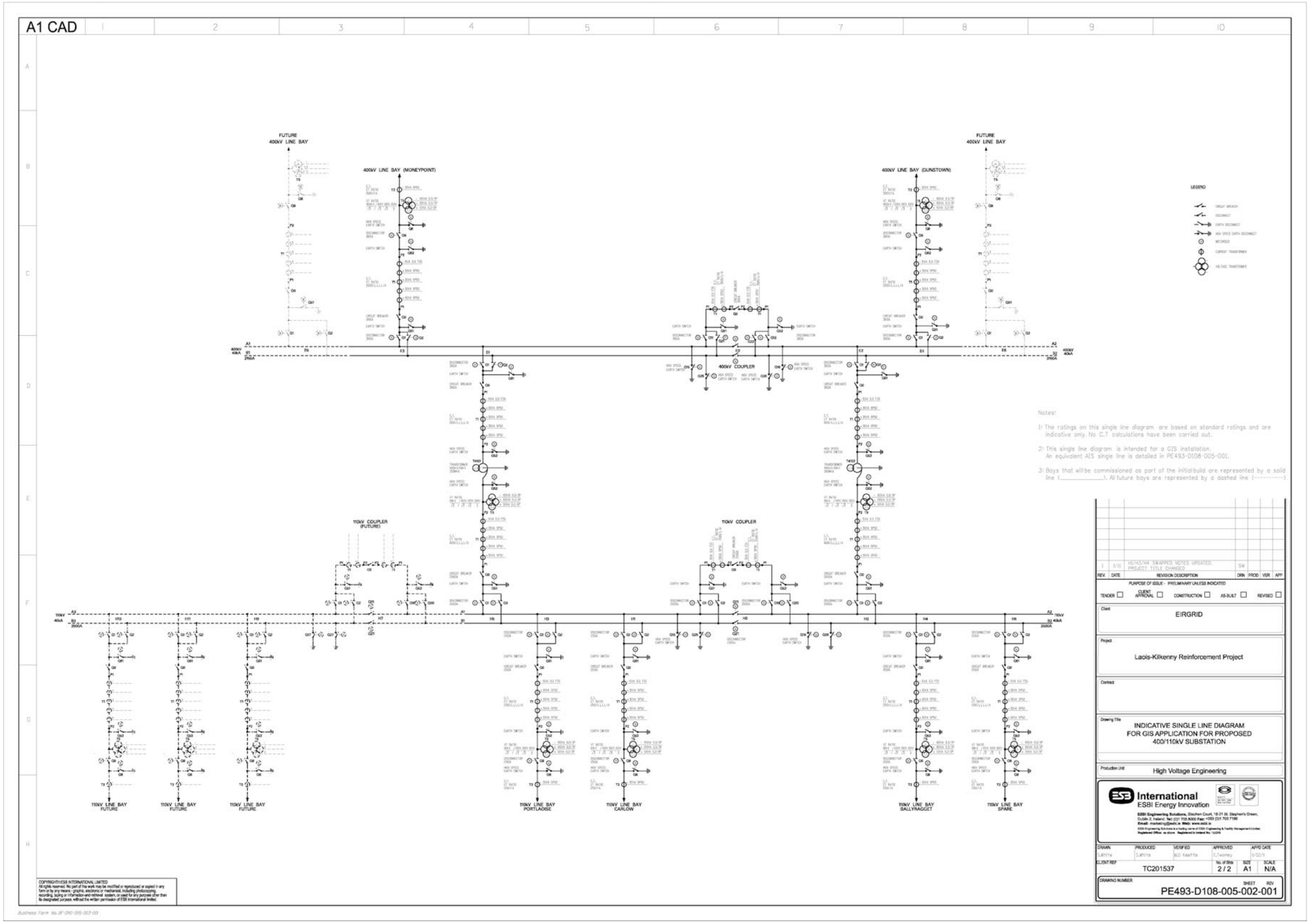
****NOTE:** This is based on the initial GIS developments providing one spare bay due to the arrangement of the switchgear.

Appendix B: Single Line Diagrams

Option 2 (GIS Arrangement)



Option 2 (GIS Arrangement)



Appendix C: Civil Costs

Indicative Budget Estimate for the 400kV/110kV GIS versus AIS

The following is the Schedule of Exclusions from this Budget Estimate

- VAT
- Professional Fees
- Contingency Sum
- Phasing
- Fire Cert
- Future Cost Inflation
- Site Investigation
- Abnormal ground conditions
- Detailed design
- Planning Application Charges
- Charges and connections/diversions to public utilities and services
- Temporary building, roads and services, accommodation for the clients employees or agents
- Temporary electrical materials storage compound (if required)
- Site Access Road
- Any works beyond the compound fence
- Removal of existing structures on proposed site

Appendix D: Operation & Maintenance

The table shown below and overleaf lists the types of tests done for AIS and GIS switchgear.

Substation Component	Planned Maintenance Intervals and Tasks				
	1 Year	5 Years	10 Years	Other Interval	Other Task
Non-critical Switchgear	▪ Operational test ▪ Infrared survey ▪ Dew point of outdoor compartments (GIS) ▪ Dew point of all compartments (MTS) ▪ Acoustic survey (GIS & MTS only) ▪ Gas leak detection survey (GIS and SF6 equipment suspected to be leaking) ▪ Lighntning Arrestor Measurements (AIS & MTS)	▪ Ordinary service ▪ Ordinary service on non-motorised sectionalisers in 110kV single busbar stations	▪ Condition assessment	▪ Monthly ▪ Age 4 ▪ 12 to 24 years (AIS: oil and SF6 only) ▪ 24 years (GIS/MTS) ▪ 20 years ▪ As required	▪ Visual Inspection ▪ Ordinary Service on sample of population ▪ Detailed service ▪ Detailed service ▪ Change SF6 dessicant in CBs/CB compartments ▪ Special Investigation

Table 6.5: Summary of Planned Maintenance Intervals and Tasks for Non-critical Switchgear

Substation Component	Planned Maintenance Intervals and Tasks				
	1 Year	4 Years	8 Years	Other Interval	Other Task
Switchgear (except items listed in table 3 above)	▪ Operational test ▪ Infrared survey ▪ Dew point of outdoor compartments (GIS) ▪ Dew point of all compartments (MTS) ▪ Acoustic survey (GIS & MTS only) ▪ Gas leak detection survey (GIS and SF6 equipment suspected to be leaking) ▪ Lighntning Arrestor Measurements (AIS & MTS)	▪ Ordinary service	▪ Condition assessment	▪ Monthly ▪ 12 to 24 years (AIS: oil and SF6 only) ▪ 24 years (GIS/MTS) ▪ 20 years ▪ As required	▪ Visual Inspection ▪ Detailed service ▪ Detailed service ▪ Change SF6 dessicant in CBs/CB compartments ▪ Special Investigation
Power transformers & reactors	▪ Infrared survey ▪ Operational test ▪ Calibration of automatic gas-in-oil monitors	▪ Ordinary service	▪ Condition assessment ▪ Diverter switch inspection (no filters)	▪ Monthly ▪ 6 months ▪ 20 years ▪ As required ▪ As required ▪ As required ▪ As required	▪ Visual Inspection ▪ Oil lab tests ▪ Diverter switch assessment if filter is fitted. ▪ Investigation when transformer/reactor is dried out ▪ Investigation following severe stress ▪ Oil Regeneration ▪ Oil Conditioning