ADDITIONAL INTERCONNECTION BETWEEN NORTHERN IRELAND AND REPUBLIC OF IRELAND

TECHNICAL REPORT - PART 1 – STUDIES APRIL 2001 TO JULY 2004

Study References:- *TREN/2000/5.7100/Z/00-007*
TREN/2000/5.7100/Z/00-008

NORTHERN IRELAND ELECTRICITY AND ESB NATIONAL GRID

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Executive Summary

The main interconnection between Northern Ireland and the Republic of Ireland is the Louth Tandragee 275kV double circuit. There are also two 110kV interconnections; Letterkenny Strabane 110 and Corraclassy Enniskillen 110. The 110kV interconnectors on their own, in the absence of the 275kV double circuit, are not sufficiently strong to join the two systems. Therefore, at present, if the 275kV double circuit trips, a remedial action scheme is in place that also trips the 110kV interconnections.

The European Commission through the TENs (Trans European Networks) funding programme is supportive of increased interconnection between member states. In 2001, funding was secured to investigate the possible benefits of increased interconnection between Northern Ireland and Ireland.

A suite of technical studies were undertaken jointly by a team of engineers from ESBNG and NIE over the period April 2001 to July 2004. The presentation of the results from these studies is provided in this report. The purpose of the technical study work is to quantify the improvement in transmission capacity and system security that would be provided by each of the interconnection options.

The major difficulty results from an unplanned outage of the existing 275kV interconnector tower line. This separates the two systems and can result in frequency stability issues.

Technical studies compared the performance of a number of interconnector development options. These are

- 110kV multi-circuit option
- Western 275kV (assumed to be Coolkeeragh Srananagh 275kV for the purpose of these studies)
- Mid Country 275kV (assumed to be Arva Tyrone 275kV for the purpose of these studies)
- Eastern 275kV (i.e. third Louth Tandragee 275kV circuit)

The studies found that the 110kV multi-circuit option does not provide a significant increase in transfer capability and is therefore not technically acceptable.

The western option, Coolkeeragh Srananagh 275kV increases power transfer to Republic of Ireland, facilitates power transfer out of Coolkeeragh and helps support the 220kV network in the north west of the Republic of Ireland. However, the transfer capacity to Northern Ireland is poor compared with the other 275kV interconnector options.

The third Louth Tandragee 275kV circuit would offer increased power transfer capability in both directions. This option is however considered unsuitable because there is a significant risk of loss of all three interconnectors and cannot therefore be considered further. This is

because all main interconnections would terminate in both Louth and Tandragee and also the routes of the new and existing 275kV circuits would not be sufficiently separate. Louth Tandragee therefore cannot be considered to solve the system separation problem.

The mid-country option offers increased transfer capability in both directions. It offers physical and geographical separation from the existing interconnection, thereby eliminating the risk of the system separation.

Based on these technical studies, carried out between April 2001 and July 2004, the mid-country option is the preferred option. A decision on whether to progress an interconnector will depend on an economic analysis and on regulatory input. A final decision on which interconnector option to progress will depend on a pre-feasibility of the route corridor and assessment of other factors.

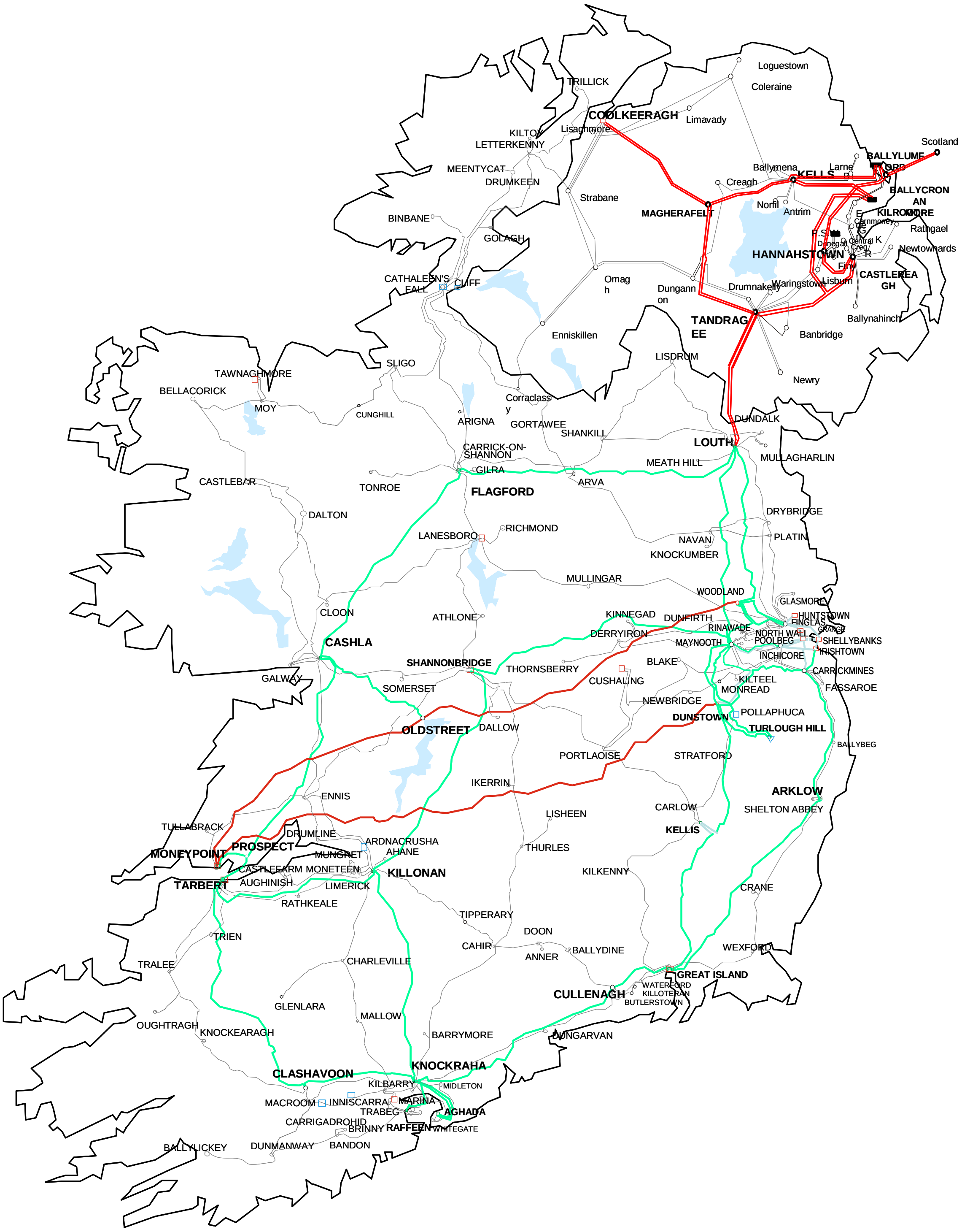
In addition to any proposed additional interconnection, internal network reinforcement may be required in order to maximise the benefit of the additional interconnection for flow in both directions. These include reinforcing the Dublin Louth corridor and locating a large SVC in Northern Ireland, possibly at Castlereagh 275kV station.

The production of the report and further work on routing, economic and stakeholder analysis was part funded by EU TENs programme. Both NIE and ESBNG acknowledge the support.

1 Introduction

The Northern Ireland electricity transmission network consists of 275kV double circuits and 110kV single and double circuits. The Republic of Ireland transmission network consists of single circuits of 400kV, 220kV and 110kV.

The main interconnection between Northern Ireland and the Republic of Ireland is the Louth Tandragee 275kV double circuit. There are also two 110kV interconnections; Letterkenny Strabane 110 and Corraclassy Enniskillen 110.



The existing 110kV interconnectors on their own, in the absence of the 275kV double circuit, are not sufficiently strong to join the two systems. Therefore, at present, if the 275kV double circuit trips, a remedial action scheme is in place that also trips the 110kV interconnections.[1] A perceived benefit of an additional interconnection is that this remedial action scheme could be disabled.

The European Commission through the TENs (Trans European Networks) funding programme is supportive of increased interconnection between member states. In 2001, funding was secured to investigate the possible benefits of increased interconnection between Northern Ireland and Ireland.

The investigation comprises two parts. First, to assess the increase in transfer capability that would be achieved by the various interconnector options, a suite of technical studies were undertaken jointly by a team of engineers from ESBNG and NIE over the period April 2001 to July 2004. Second, in order to assess the benefit of this increase in transfer capability, an economic assessment and a stakeholder consultation were carried out.

The presentation of the technical results is provided in this report. The purpose of the technical study work is to quantify the improvement in transmission capacity and system security that would be provided by each of the interconnection options.

Early in the project, the steering committee for the joint studies agreed on a limited number of interconnector development options that would be subjected to a comprehensive technical investigation. The interconnector development options are as follows:

- 110kV project
  - Coolkeeragh Trillick 110kV line
  - Louth Newry 110kV line
  - Tandragee Lisdrum 110kV line

- Arva Tyrone 275kV circuit as an example of a mid-country option

- Coolkeeragh Srananagh 275kV circuit as an example of a western option

A further option, Louth Tandragee 275kV was added later and results are included in section 4.5.2.

The findings of this report are divided into the following sections

- <u>System Separation</u>
  With the existing Northern Ireland/Republic of Ireland interconnection arrangement, it is possible for the two systems to become electrically separated due to a single key outage event. This section of the report determines the potentially severe impact of such an event on both systems, and identifies the associated constraints on allowable power transfer.

[1] This scheme can also send a run back signal to the Moyle DC interconnection between Northern Ireland and Scotland.

- Loadflow Analysis
  This section is concerned with the steady-state performance of the joint Northern Ireland/Republic of Ireland transmission system, in terms of voltages and power flows on the system. The studies investigated the impact of both planned and unplanned outages, and the results quantify the allowable level of Northern Ireland/Republic of Ireland power transfer for the existing system and also for each of the proposed interconnection options. As part of this work, a number of "internal" transmission constraints were identified. These are constraints that occur within the individual systems and are not strictly associated with any particular interconnector.

- Maintenance
  The impact of transmission maintenance outages on available transfer capacity is quantified.

- Fault Analysis
  The impact of each of the proposed interconnection options on system fault levels is quantified.

- Wind Generation
  A scenario was investigated to show the main technical impacts of increased wind generation on the case for additional interconnection.

- Transient Stability
  The construction of additional interconnectors will alleviate the issue of system separation, as no single outage event could then separate the Northern Ireland and Republic of Ireland systems. However, in this case it is important to ensure that stability will be maintained between the two systems for a worst-case interconnector trip. This section of the work quantifies any constraints arising from this issue.

- Small Signal Stability
  This section investigates the response of the joint transmission system to small signal disturbances – that is voltage and frequency fluctuations caused by natural load variations or planned switching events.

Routing, economic and stakeholder impacts are considered in other work and hence are not referred to in this report. System studies to investigate the performance are numerous and NIE / ESBNG acknowledge the valuable contribution which IPSA Power made to automation of the work and reporting.

2 Identification of Interconnection Options for Study

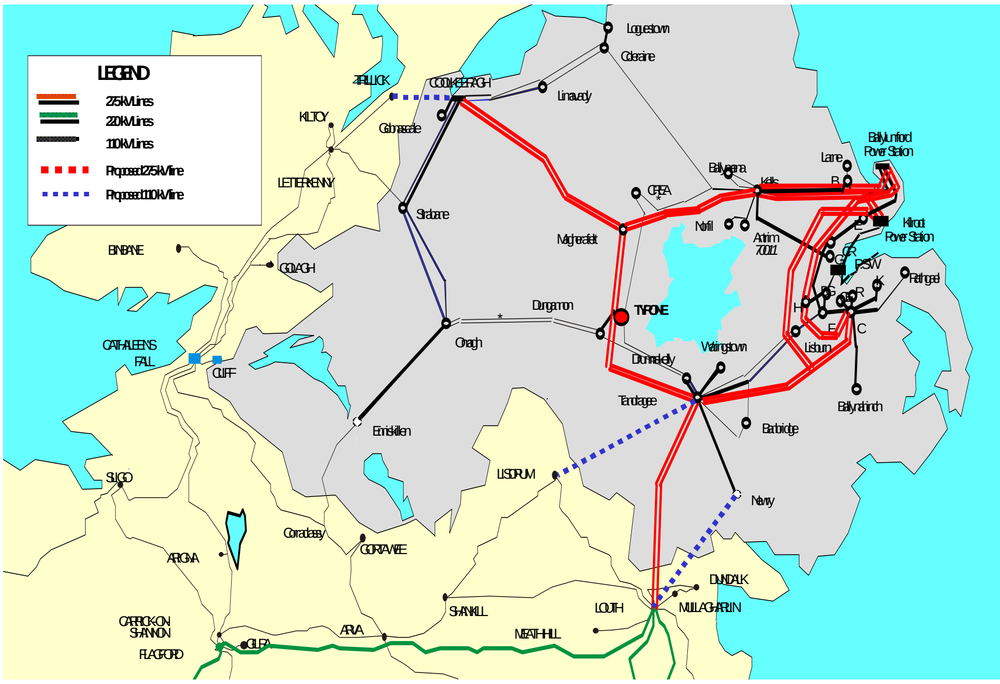
Interconnector development options investigated were selected by the project steering committee. The following assessment was used in the selection of the options for further study.

2.1 INTERCONNECTION DEVELOPMENT OPTIONS

In the event that ESB and NIE decide to develop further interconnection between the two systems, such development is likely to be at 110kV or at 275kV. NIE and ESB have agreed to participate in joint studies which will compare the performance of 110kV and 275kV interconnection development options. A range of potential interconnector development options are summarised here with an explanation of how these are related to the development options that were studied in work undertaken by NIE and ESB between 1995 and 1997.

Based on that earlier work, a 110kV development option and a 275kV development option have been selected for further study. In the event of a 275kV development being preferable, the merits of constructing such a project at 400kV construction will be investigated.

110kV Development



Given the existing 110kV transmission infrastructure, the choice of 110kV development options is relatively straightforward. The 110kV interconnection development option consists of three 110kV lines:

- Coolkeeragh - Trillick 110kV line
- Louth - Newry 110kV line
- Tandragee - Lisdrum 110kV line

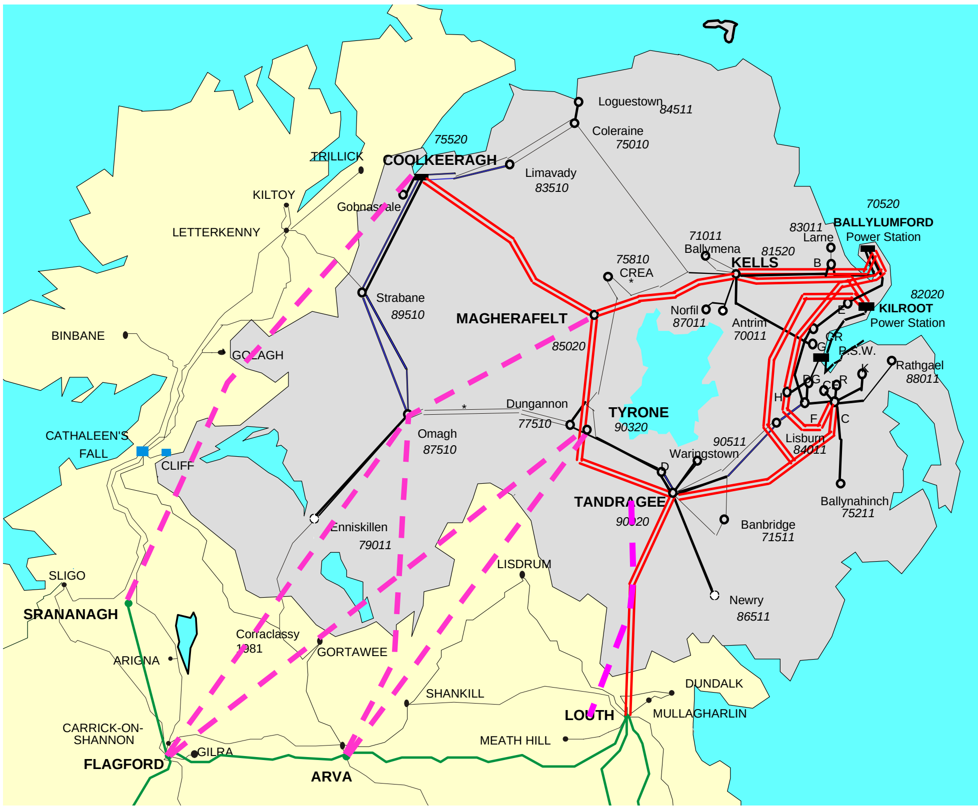
These are in addition to the existing two 110kV lines at

- Letterkenny - Strabane 110kV line
- Corraclassy - Enniskillen 110kV line

Preliminary studies quickly showed Louth Newry 110kV line to be preferable to a Dundalk Newry 110kV line. Although Dundalk Newry 110kV line would be a shorter line, the Louth Dundalk 110kV lines are already quite highly loaded and consequently would form a bottleneck to power flow from ESB through Dundalk to NIE.

For the line routes to be studied, the detail may be adjusted as required in order to optimise the impact of the 110kV options:-
Add phase shifting transformers as required on each of the new 110kV lines
Static VAr Compensation can be added as required to solve voltage problems
If necessary, the rating of the proposed 110kV lines may be adjusted for different line construction types, i.e. if 200 sq mm rating is restrictive, replace in the studies with 300 sq mm.

275kV Development



Existing 110kV		Potential 275kV	
Existing 220kV			
Existing 275kV			

A detailed appraisal of 275kV options was performed in the 1995 to 1997 studies. The conclusion of those studies is outlined in the report: "Co-ordinated Transmission Development in the NW of Ireland", ESB - NIE Joint Studies. The options considered were
Moy - Cavan
Moy has since become Tyrone 275kV station.

Magherafelt – Omagh - Cavan
Magherafelt – Omagh - Flagford
Omagh was proposed for development as a 275kV station.
Coolkeeragh – Flagford

The current range of possible 275kV interconnection development options are as follows:
Louth Tandragee additional 275kV line
Magherafelt - Arva 275kV line.
Magherafelt - Flagford 275kV line
Tyrone - Arva 275kV line
Tyrone - Flagford 275kV line
Tyrone is a proposed NIE 275kV station near to Dungannon.
Coolkeeragh - Srananagh 275kV line.
Srananagh is a proposed ESB 220kV station.

A **Louth Tandragee additional 275kV line** would be the shortest of the possible 275kV options. A number of considerations mitigate against this option. There is the strategic benefit of geographic separation from the existing Louth Tandragee 275kV interconnection. Also, locating transmission infrastructure further west than the already well supplied eastern corridor may be of some future benefit.

The Magherafelt Omagh Cavan 275kV circuit was the recommended option in the 1997 report. Geographically this would be similar to a **Magherafelt Arva 275kV line**. The original option was found to provide good technical performance and, significantly, was in line with NIE's strategic view on network development in 1997, which proposed an Omagh 275kV station to support NIE's 110kV network in the north west. Today, NIE is developing Tyrone 275kV station (previously known as Moy) near Dungannon and has no plans for a 275kV station at Omagh. In the light of NIE's revised plans for the area, there is no longer a compelling reason to route a 275kV line near Omagh. Both options involving Magherafelt are now ruled out in favour of options involving the new Tyrone 275kV station. Since Tyrone is geographically closer to the border than Magherafelt, interconnector developments from Tyrone would be shorter and consequently less expensive than developments from Magherafelt. The option will demonstrate the characteristics of an Eastern 275kV development.

A Moy Cavan 275kV line was considered in the 1997 report. The indicative Moy 275kV station discussed in the 1997 report has become the proposed Tyrone 275kV station. In 1999, ESB commissioned Arva 110kV station in county Cavan and that site has sufficient space to make Arva a good location for termination of a new 275kV interconnector. Therefore, Moy Cavan has now become the **Tyrone Arva 275kV line** option. This option was rejected in the 1997 report in favour of a reinforcement based around a proposed NIE 275kV station at Omagh. In the absence of Omagh, the Tyrone Arva 275kV line now becomes the recommended option for study. A Tyrone Arva 275kV interconnection would give similar technical performance to the options from Magherafelt but the line routes would be shorter and any project would be significantly less expensive. The option will demonstrate the characteristics of a mid-country 275kV development.

Magherafelt Flagford 275kV line and **Tyrone Flagford 275kV line** options would give similar technical performance to Tyrone Arva 275kV. Both options involving Flagford are ruled out because according to the 1997 report "the Omagh to Border section is considered not viable." The picturesque Enniskillen lake and town area is a factor in this conclusion. Avoiding the lakeland area with the Tyrone Flagford 275kV line option would result in a line that was essentially Tyrone Arva 275kV plus a new Arva Flagford 275kV line. This option is equivalent to a Tyrone Arva interconnector and an Arva Flagford 275kV line. It is therefore considered that by studying Tyrone Arva, the interconnector portion of Flagford Tyrone is assessed.

A Coolkeeragh Flagford 275kV development option was considered in the 1997 report. Since then ESB have received capital approval for Srananagh 220kV station. Consequently, Coolkeeragh Flagford has now become the **Coolkeeragh Srananagh 275kV line** option. This option would provide the greatest geographical separation from the existing 275kV interconnection. An attraction of this option is that it helps to get power out of the Coolkeeragh area, which could be an advantage to NIE if significant wind power was to locate in the area. In the 1997 report this option was found to provide inferior technical performance and was therefore ruled out. Phase 1 of that report referred to Coolkeeragh as a "weak" node on the NIE system. The replacement of several small Coolkeeragh sets with a single 400 MW combined cycle does not increase the strength of this node, nor does the possible location of wind generation there. This would demonstrate the characteristics of a western 275kV interconnector.

275kV Conclusion – Investigate both Arva Tyrone 275 and Coolkeeragh Srananagh 275

In the work undertaken between 1995 and 1997 by ESB and NIE, the Arva Tyrone 275kV option (or equivalent) was identified as being the best compromise 275kV option. Consequently, this option will be examined. However, the possible strategic benefits of a Coolkeeragh Srananagh 275kV circuit are sufficiently significant to warrant the investigation of this interconnector development option too.

The detail of the proposed Arva - Tyrone 275kV interconnector development option to be studied is as follows

Line routes shown in the diagram are indicative only. The actual line routes may vary significantly from those shown.

To connect a 275kV line at Arva requires a 275 / 220kV transformer. The new line shall be a single circuit 275kV line. Development of the 220/110kV part of Arva is included as part of this proposal.

The detail of the proposed Coolkeeragh - Srananagh 275kV interconnector development option to be studied is as follows

Line routes shown in the diagram are indicative only. The actual line routes may vary significantly from those shown.

To connect a 275kV line at Srananagh requires a 275 / 220kV transformer.

The new line shall be a single circuit line of at least 275kV.

Additional 220/110kV transformer capacity at Srananagh is required as part of this proposal.

Construct at 275kV or 400kV? The joint studies will determine whether a 275kV interconnection is preferable to multiple 110kV interconnection. In the event of the 275kV interconnection being preferable, should the new circuit be constructed as 275kV or 400kV? There could be some long term strategic benefit to constructing any new line to 400kV construction. For example, the existing Louth Tandragee 275kV double circuit is operated at 275kV but is constructed to 400kV specification.

A sensitivity analysis will be performed to compare the performance of a development with 275kV line construction parameters with the performance for 400kV construction parameters.
Convert Louth Tandragee Double Circuit to 400kV?
The existing Louth - Tandragee 275kV double circuit is operated at 275kV but is built to 400kV construction. There is then the option of converting it to 400kV operation. Traditionally, the loss of the existing Louth - Tandragee 275kV double circuit is considered to be a credible contingency and available transfer capability is limited by this contingency.

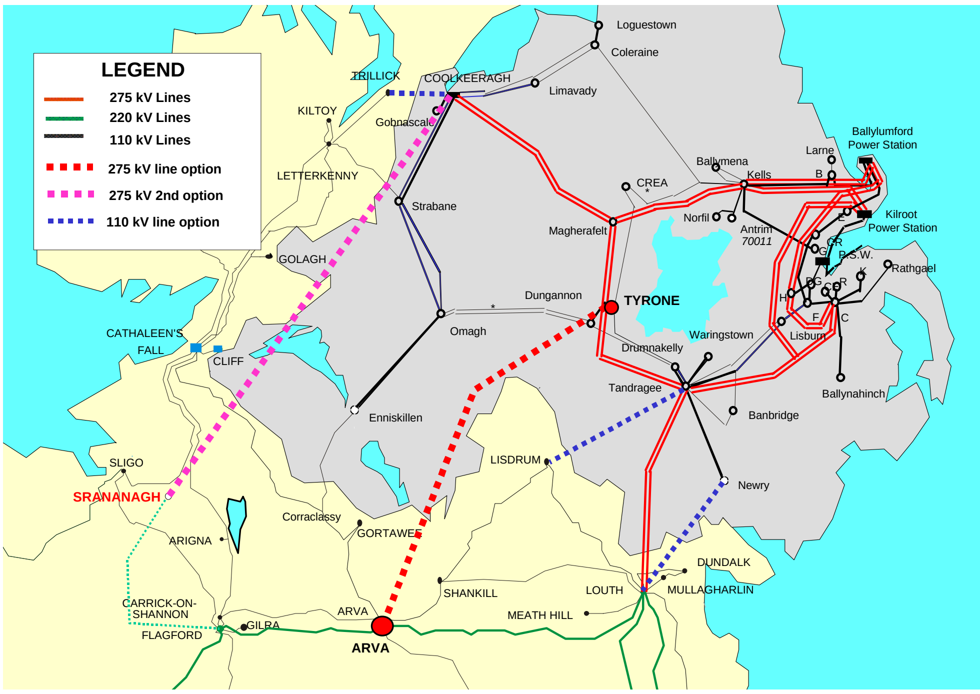
Uprating the line to 400kV will not increase the available transfer capability without additional reinforcement or unless it is decided that the loss of the double circuit is no longer a credible contingency.

The studies will determine the extent to which Louth - Tandragee 275kV limits the available transfer capability both with and without further interconnection. If Louth Tandragee 275kV double circuit proves to be a significant bottleneck, converting the double circuit to 400kV can be re-examined. The existing capacity of each Louth Tandragee 275kV circuit is in excess of 710 MVA and consequently line rating is unlikely to be a limiting factor. Should ESB decide to build any additional line from Dublin to Louth at 400kV this would influence the decision to operate Louth Tandragee at 400kV. At present, ESB have no plan to do this.

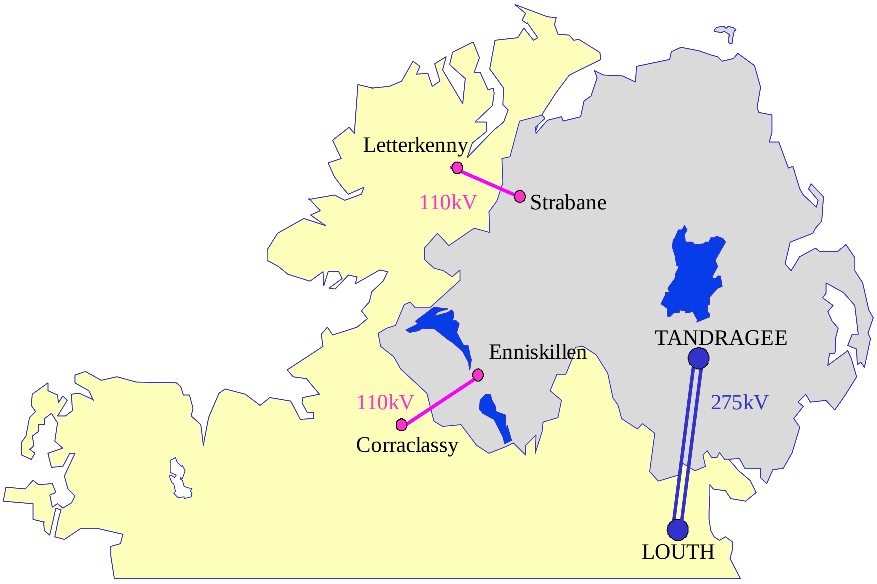
Conclusion

A 110kV interconnection development option involving three 110kV lines is to be compared with two single circuit 275kV line options, one from Tyrone to Arva and one from Coolkeeragh to Srananagh.

In the event of a 275kV project giving superior performance to the 110kV development option, a sensitivity analysis will be performed on the impact of developing the project using 400kV construction.



3 System Separation



The main interconnector comprises three 220/275 kV transformers and one double-circuit[2] 275 kV between Louth and Tandragee. There are also two 110 kV standby connectors which were constructed in 1993/94. The 110kV standby interconnectors are not sufficiently strong to support interconnection between the two systems when acting alone.

For this reason, there is a remedial action scheme in place to guard against the loss on fault of the Louth Tandragee 275kV double circuit. If the Louth Tandragee 275kV double-circuit trips, a trip signal is sent to the 110kV interconnectors causing them to open. In other words, current practice is to separate the Republic of Ireland and Northern Ireland transmission systems for the loss of Louth Tandragee 275kV double circuit.

The scheme works for moderate power transfers but for larger transfers the resulting power imbalances after separation deliver a severe shock to both systems. Even accounting for Northern Ireland's ability to utilise the DC link to Scotland, there is a power transfer limit at which the implications of system separation are deemed unacceptable. Furthermore, the Northern Ireland to Republic of Ireland transfer capability is determined by the flow on the Moyle HVDC line, which is uncertain.

An investigation is performed to quantify the maximum power transfer in either direction for which a system separation can be tolerated by both systems. This maximum power transfer is defined as the system separation limit. This system separation limit is often the main restriction to cross border power exchange between the two systems.

On construction of a further interconnection, there will be no system separation and the special protection scheme in its present form will cease to operate. This will allow the 110kV circuits in the west to remain in service even for an outage of the Louth Tandragee 275kV double circuit. This allows greater flexibility in identifying local reinforcements.

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[2] Two separate transmission lines strung on a single set of towers.

3.1 Reliability and Restoration of Existing 275kV Interconnection

The perceived reliability of the Louth Tandragee 275kV double circuit is a very important consideration when examining the system separation question.

In 1975, this double circuit was retired following a period of repeated malicious damage. In 1995, as the peace process in Northern Ireland became established, the Louth Tandragee 275kV was restored to service. Since that date, this double circuit has not tripped on fault as a single contingency.

There have been some incidents of other 275kV double circuits in Northern Ireland tripping in recent years, and therefore it is appropriate to continue to consider the loss of the Louth Tandragee 275kV double circuit as a credible outage. Causes of double circuit trips include: lightning, protection maloperation, accidents and malicious damage.

In the event, of significant damage being done to the 275kV overhead line (i.e. destruction of a limited number of transmission towers), it would be expected that the lines could be returned to service in approx one to two weeks.

In summary, the reliability of this circuit is treated the same as all other 275kV double circuits on the Northern Ireland system, and the loss of the 275kV Louth Tandragee double circuit and consequently the system separation is a credible occurrence. Northern Ireland Electricity considers the loss of other 275kV double circuit outages as credible.

3.2 Generator Performance

Monitoring Performance

An important consideration here is whether all the generators are actually capable of responding to a system separation. This is important since any dynamic studies are based on the assumption that all generator power output is responding as designed. Each system operator needs to ensure that all generators provide their share of reserve.

Grid Code

In addition, the system operators need to be confident that the generators meet the required operating performance with regard to frequency variation for generators as specified in the Grid Codes. The Republic of Ireland grid code specifies the following performance.

CC.7.3.1.1 Each **Generation Unit**, shall, as a minimum have the following capabilities:

(b) remain synchronized to the **Transmission System** at **Transmission System Frequencies** within the range 47.5 Hz to 52.0 Hz for a duration of 60 minutes.

(c) remain synchronized to the **Transmission System** at **Transmission System Frequencies** within the range 47 to 47.5 Hz for a duration of 20 seconds required each time the frequency is below 47.5 Hz.

(d) remain synchronized to the **Transmission System** during rate of change of **Transmission System Frequency** of values up to and including 0.5 Hz per second.

Northern Ireland Grid Code connection conditions relating to frequency and voltage are as follows:

CC5. SUPPLY STANDARDS

CC5.1 The **frequency**, voltage and harmonic design criteria of the **NIE system** are set out in **CC5.3 to CC5.5**.

CC5.2 Each **User** shall ensure that its **Plant** and **Apparatus** at **Connection Points** is capable of operating under any variation in the **System Frequency** and voltage as set out in **CC5.3** to **CC5.5.**

CC5.3 **Frequency** Variations

CC5.3.1 The **Frequency** of the **NIE system** shall be nominally 50 Hz and shall normally be controlled within the limits of 49.5-50.5 Hz an in accordance with the Electricity Supply Regulations (N.I.) 1991.

CC5.3.2 In exceptional circumstances, **System Frequency** could rise to 52 Hz or fall to 47 Hz but sustained operation outside the range specified in the Electricity Supply Regulations (N.I.) 1991 is not envisaged. **Users** should take these factors into account in the design of **Plant** and **Apparatus**.

CC5.4 Voltage Variations

CC5.4.1 The voltage variation on the **NIE Transmission System** shall comply with the Electricity Supply Regulations (N.I.) 1991, that is, will normally remain within the limits +- 10% of the nominal value or as otherwise agreed.

CC5.4.2 The voltage variation to **Customers** connected to the **NIE Distribution System** shall comply with the Electricity Supply Regulations (N.I.) 1991, that is, will normally remain within +-6% of the nominal value or as otherwise agreed.

CC5.4.3 The design criteria in respect of voltage fluctuations and unbalance shall be in accordance with the **Licence Standards**.

[Rev 4 12.02.02]

Transmission Planning Criteria

The reference in the Transmission Planning Criteria is as follows:

2.1.2 Less Probable Contingencies

For system integrity, the system should be able to withstand more severe but less probable contingencies without going into voltage collapse or uncontrolled cascading outages.

3.3 Simulation of System Separation

A number of dynamic simulations were performed to support the investigation into the consequences of system separation and these are presented here.

When a system separation occurs during larger power transfers, this can lead to severe frequency disturbances and the objective of this study is to investigate the magnitude of the frequency deviations and to determine whether the systems would stay within the acceptable rate of change of frequency for both systems for different power transfer levels. The simulations also monitored generator angular stability.

The remedial action scheme to inter-trip the 110kV interconnections, i.e. system separation, is simulated. A fault is applied to the 275kV bus at Tandragee 275kV circuit. 75ms later the Louth Tandragee 275kV double circuit is tripped. 125ms after this trip, the remedial action scheme operates and trips the 110kV interconnection.

For transfer scenarios for power from Northern Ireland to Republic of Ireland with Moyle DC link generating, the Moyle run-back facility is also used. This is part of the remedial action scheme and helps to arrest the frequency rise in Northern Ireland.

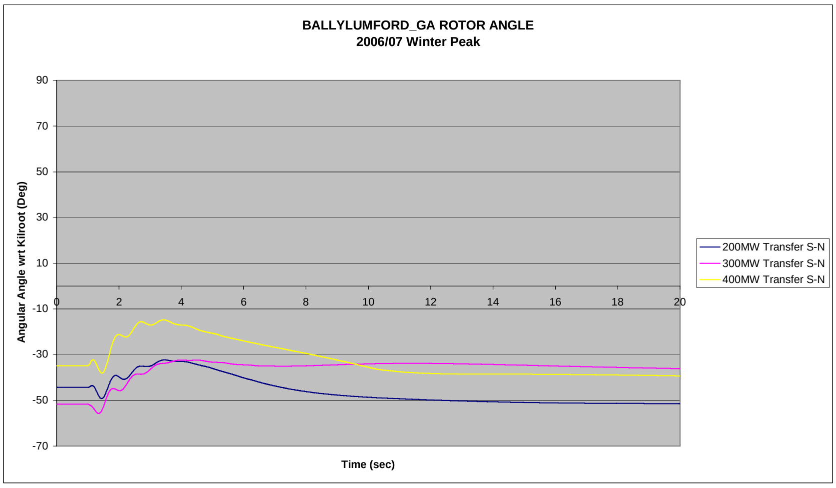
The results from the dynamic simulations can be summarized as follows:

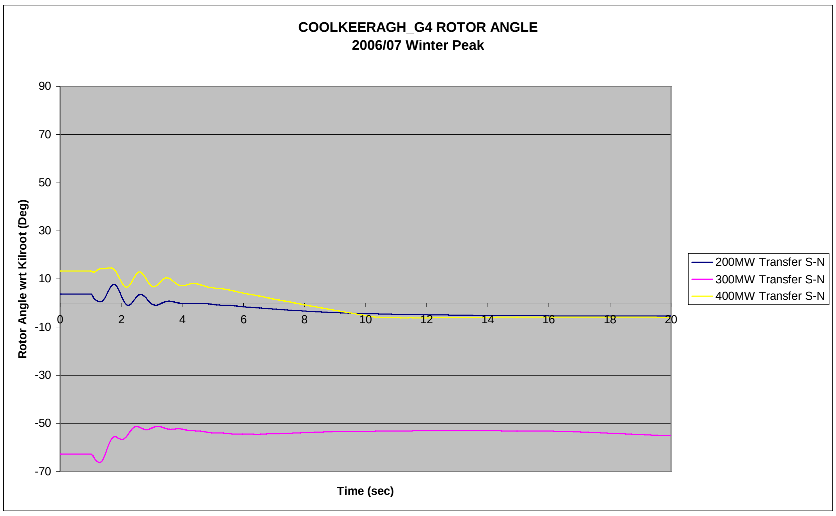
Power Transfer	Transfer level for maintaining stability	Load shed scheme frequency 48.5Hz	Maximum Frequency
North – South	600 MW winter (Moyle 450MW) 300 MW summer min.	7 s n/a (49.2 Hz)	50.45 Hz 50.6 Hz
South – North	400 MW winter	7 s	50.35 Hz

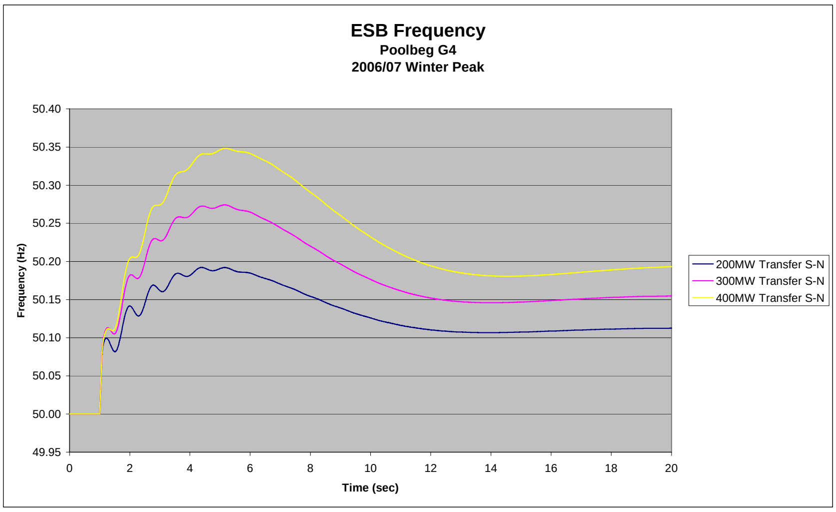
A finding of the study is that the larger Republic of Ireland system is usually less affected by system separation than the smaller Northern Ireland system.

SOUTH to NORTH Transfer

A number of traces for the simulation of the system separation following various south to north power transfers are shown below. At moderate power transfer levels, there are no system stability issues in Northern Ireland. However, for the 400 MW transfer to the Republic of Ireland, the rate of change of frequency on the Republic of Ireland system is quite high compared to the performance specified in the Grid Code. CC.7.3.1.1 (d) requires generation to remain synchronized during rate of change of Transmission System Frequency of values up to and including 0.5 Hz per second.

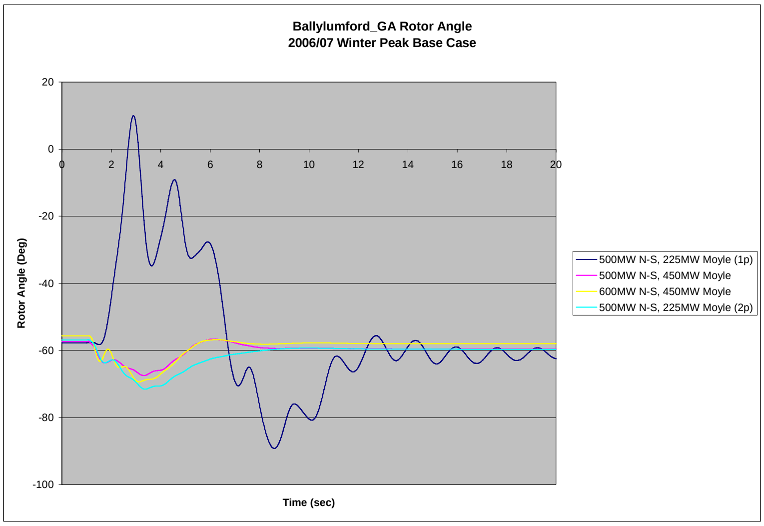


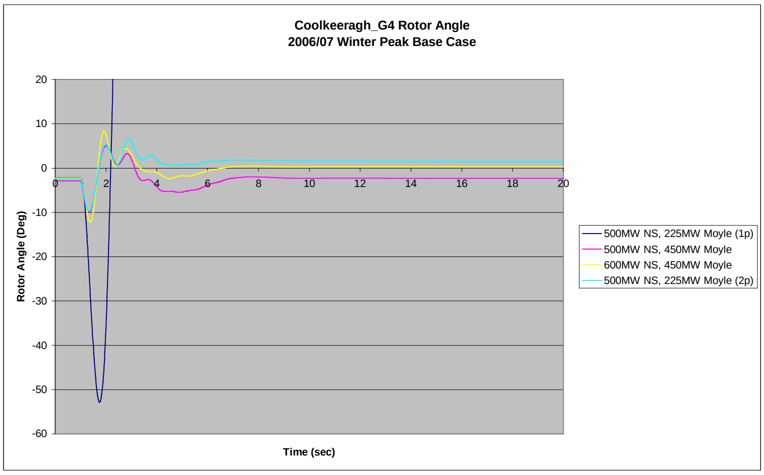


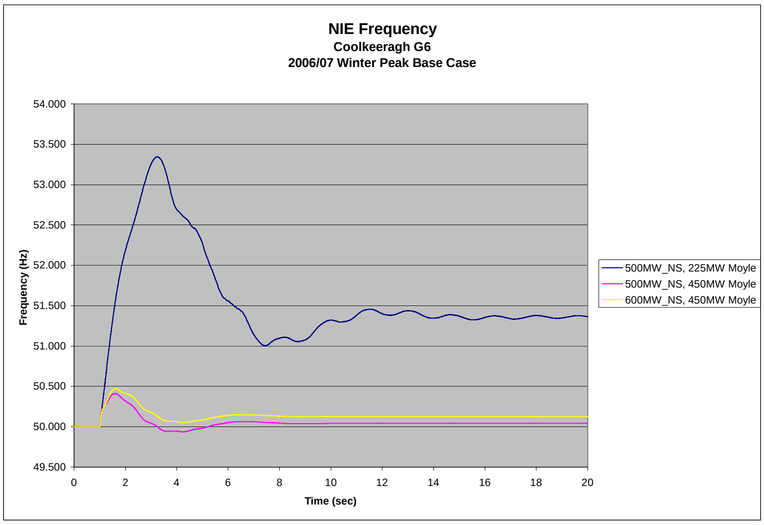


NORTH to SOUTH

The following graphs illustrate that the Northern Ireland generators lose stability for power transfers of 500MW to Republic of Ireland when there is only one pole in service on the Moyle DC link to Scotland. This is because the full rescue action of the DC link is not available to secure the Northern Ireland system. At large power transfers, the presence of the two poles at Moyle, and therefore the fast ramp back facility is crucial to maintaining stability of the Northern Ireland system.

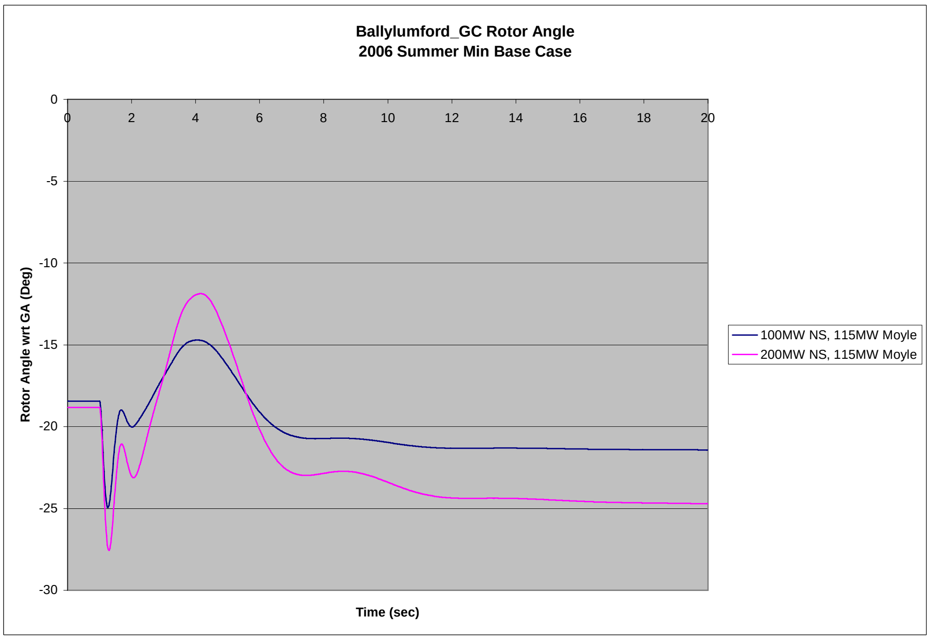


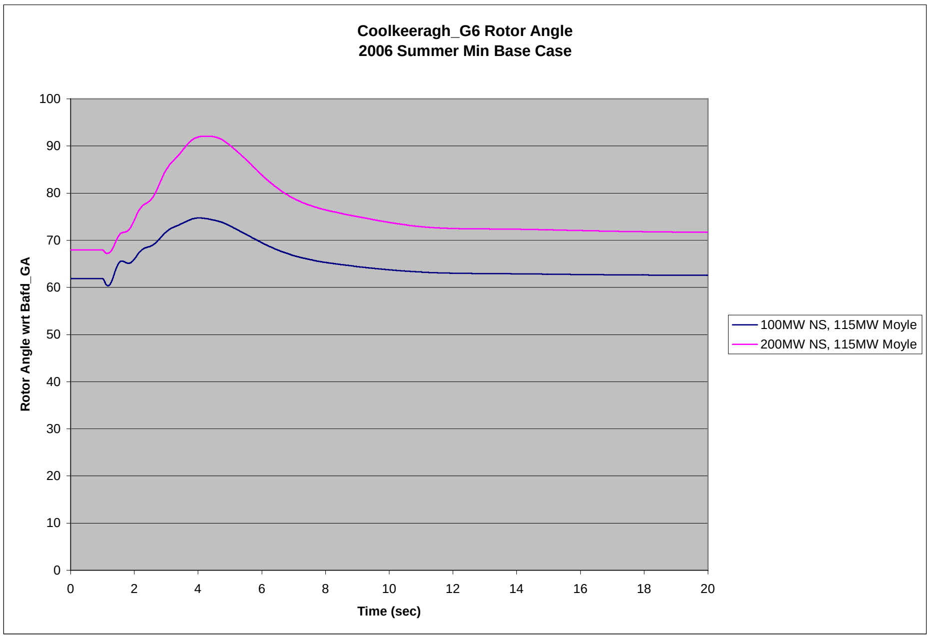




Summer Minimum

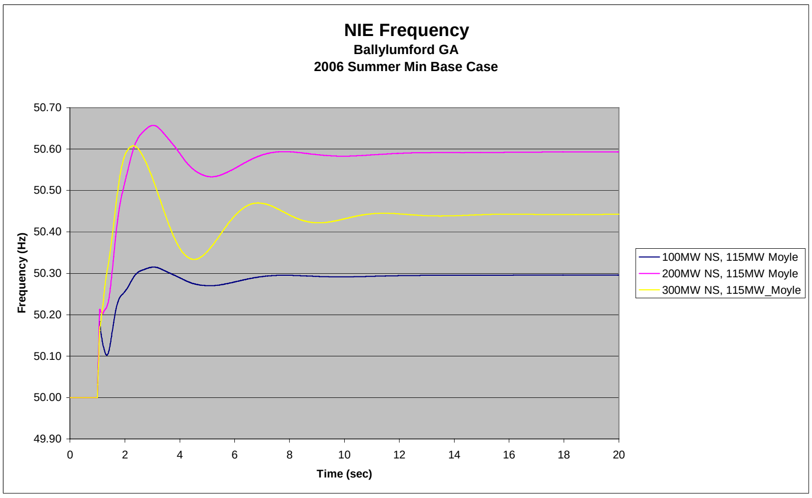
The following graphs illustrate the system performance for a system separation during various power transfers from north to south. During the transfers, the DC link to Scotland is importing 115MW with ramp back available.

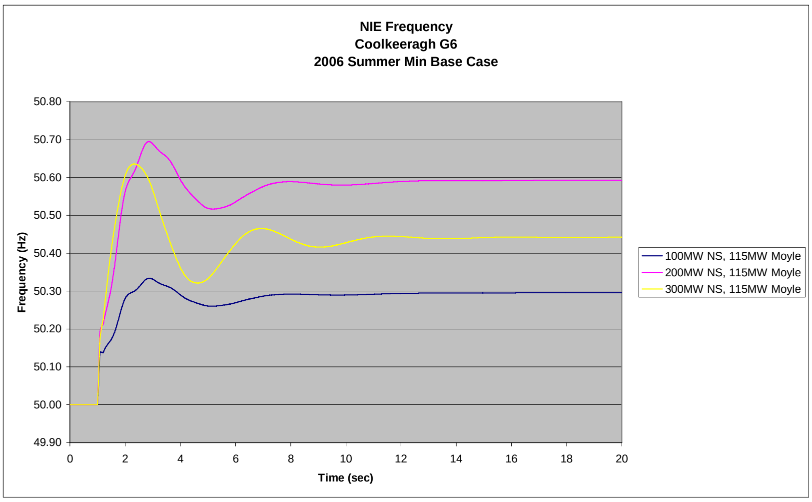


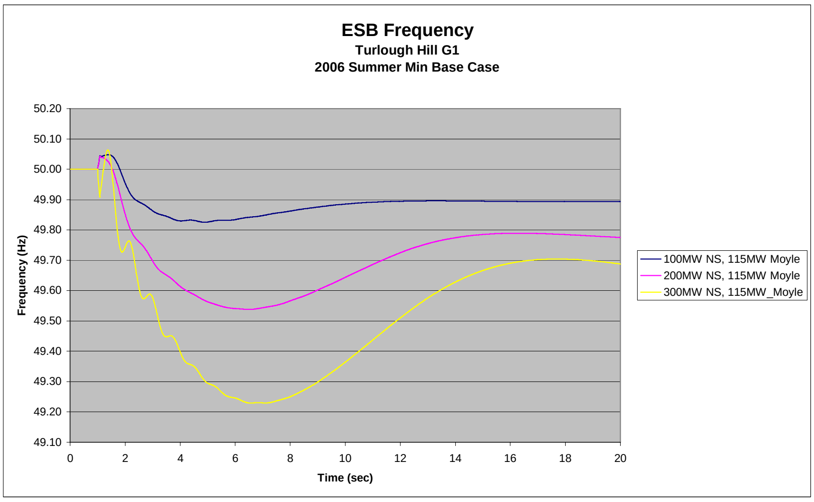


None of the generators show any signs of angular instability. I.e. there is no pole-slip evident from the graphs. However, the frequency change is quite significant. This is because the trades appear to be a very large fraction of the system demand at this low load period.

It is not expected that there will be excessive interest in power transfer at summer night valley conditions. It is expected that both system operators will maintain their networks with local generation to adhere to operational guidelines. However, market forces or differences in market rules or the availability of wind generation may change this. The studies show the significant impact of system separation at lower load levels.







At night valley conditions, it is expected that both systems will have generators at very low power levels. There is a concern that at these low limits, generators will not be as responsive as at their normal operating points. In addition, the exporting system has the disadvantage that, with generators near their minima, there is little scope to respond to a sudden loss of load by further reducing generation. This would be required following a system separation.

3.4 System Separation Limit

A meeting between system operators and power system planners from both ESB National Grid and Northern Ireland Electricity was held in Ballymascanlon Hotel on November 3rd, 2003. The purpose of this meeting was to outline the problems associated with system separation at large power transfers and to propose a system separation limit.

In order to calculate the maximum transfer limit, the Republic of Ireland and Northern Ireland systems need to be considered individually. On both systems there are limits associated with power shortages and power surpluses. The transfer limit in a given direction then is the lower of the two system's capabilities.

Each system operator holds responsibility for deciding on an acceptable import and export in respect of their own system. This value will vary with specific operating conditions.

System separation is more severe for each system individually than the loss of the largest infeed on the combined system. For the large trades being considered, the power transfers across the border are likely to be larger than the largest infeed on either system.

The system that had been importing power will have to replace the imported power, either with generator reserve or load shedding.

The system that had been exporting power will have to cope with the excess generation, either by generators in response to the frequency rise or for NIE by reducing infeed from the Moyle DC link. A power surplus will cause a high frequency on that system unless action is virtually instantaneous.

At the meeting it was suggested that there should be no more than a 20% reduction in output of a generator as this can lead to generator boiler problems and the generator may trip. The ability of the Northern Ireland system to absorb excess generation is facilitated by the ability of the Moyle DC link to Scotland to run back very quickly from its existing import to as low as zero MW.

Coping with Power Surplus and Power Deficit

The main problems that accompany system separation between Republic of Ireland and Northern Ireland during large power transfers are as follows.

- System and Generator Stability
  If a system separation occurs during a power transfer, the resulting power imbalances after separation will deliver a severe shock to both systems. It is important that the resulting isolated transmission systems are capable of withstanding that shock, without a major loss of generation or system collapse.

  - High or low Frequency
    If the frequency becomes either two high or two low, generation will disconnect from the transmission networks.

  - Rate of Change of Frequency
    Generators on the Republic of Ireland and Northern Ireland systems are required to be able to deal with a rate of change of frequency of 0.5 Hz / sec and 1.5 Hz / sec respectively.

- Acceptable level of load shed

- Tertiary Reserve
  Ability to restore load quickly after the separation

Import Limits

When a large power import is lost, the system makes up the immediate power shortfall in two ways. First, the generator reserve on the system should pick up. Second, if this is not enough, load will be shed by the under-frequency load shed schemes.

Northern Ireland experience suggests that their import limit is approx the generator reserve plus 10% of system demand. The separation limits are quoted using % values because the under-frequency load shed schemes are configured to shed percentages of the system load.

- The Northern Ireland import limit = approx (generator reserve + 10% of system demand).

The Republic of Ireland[3] is also willing to accept a 10% loss of load but suggest that a daily figure be quoted on the load throughout the day and not just at the peak Hence,

- The Republic of Ireland import limit = approx (generator reserve + 8% of system demand).

Export Limits

When a large power export is lost, the generation on the exporting system is required to reduce its output.

Northern Ireland experience[4] suggests that 20% is the maximum reduction that their generation can handle. In addition, in the event of separation from Republic of Ireland, Northern Ireland will send a fast run back signal to the DC link reducing the power import from Scotland to near zero.

- The Northern Ireland export limit = approx (20% of system generation + pre-contingency import from Scotland)

From a system separation consideration only, given the larger size of the Republic of Ireland system, the ability to send power to Northern Ireland is always limited by the ability of Northern Ireland to import power. Hence,

- The Republic of Ireland export limit = greater than 10% of system demand

Validity of Assumptions

The operational guidelines presented in this document are based on operational experience of the systems before they were interconnected and several recent years experience of interconnection. This experience is limited to much smaller power transfers than are under consideration here. In addition, both systems are presently undergoing significant changes in technology (increased reliance on capacitor support, increased penetration of wind generation and larger generator sizes). There are fewer but larger generators on both systems than was previously the case.

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[3] Revised Jan 2005

[4] NIE are carrying out a detailed study of their plant capability and may revise this approach at a future date.

The operational guidelines presented for the system separation are therefore subject to a number of assumptions. That is, it is assumed that there are no other issues with the following

- system stability,
- rate of change of frequency,
- Moyle availability,
- the present reserve sharing arrangement continuing and
- demand continues to be met with governing machines

The operational guidelines are valid only for the figures stated and may be reviewed at a future date.

Separation Limit

A sample calculation is performed for the system at 2006/7. The separation limits derived from this consultative process are as follows:

SEPARATION LIMIT							
	System Demand			power to RoI			power to NI
TOTAL TRANSFER CAPABILITY	NI	RoI	Moyle dispatch	250	150	0	
2006/7 winter peak	1850	5000		610	566.5	432.5	295
2006 summer peak	1300	4000		513	429	295	240
2006 summer night valley	600	1650		338	254	120	141

Notes:

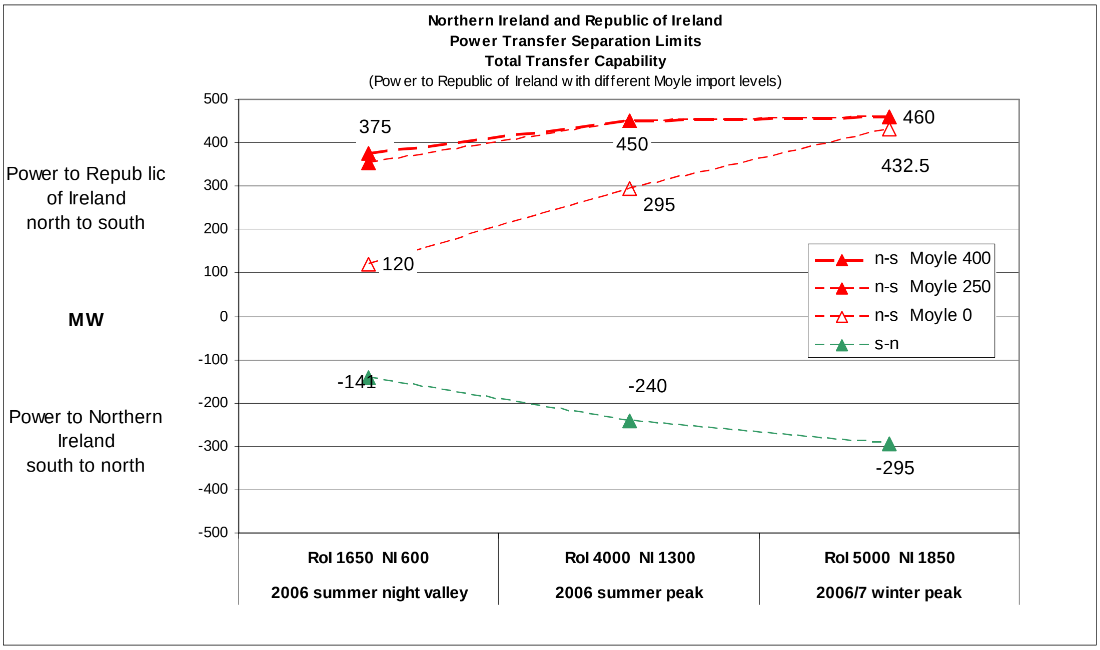
1. The figures are presented in Total Transfer Capability values.

2. The table contains the maximum load shed (when importing) or generator reduction (when exporting), expressed in MW, that are acceptable on the Northern Ireland and Republic of Ireland systems, separately.

3. The table contains values for generator reserve on both systems.
   The generator reserve figures refer to the geographical location of the reserve. I.e. it is irrelevant who pays for the reserve. For example, Republic of Ireland may pay for reserve on the DC link to Scotland or Ballylumford, or Coolkeeragh but, for system separation calculations, that reserve is considered as reserve in Northern Ireland.

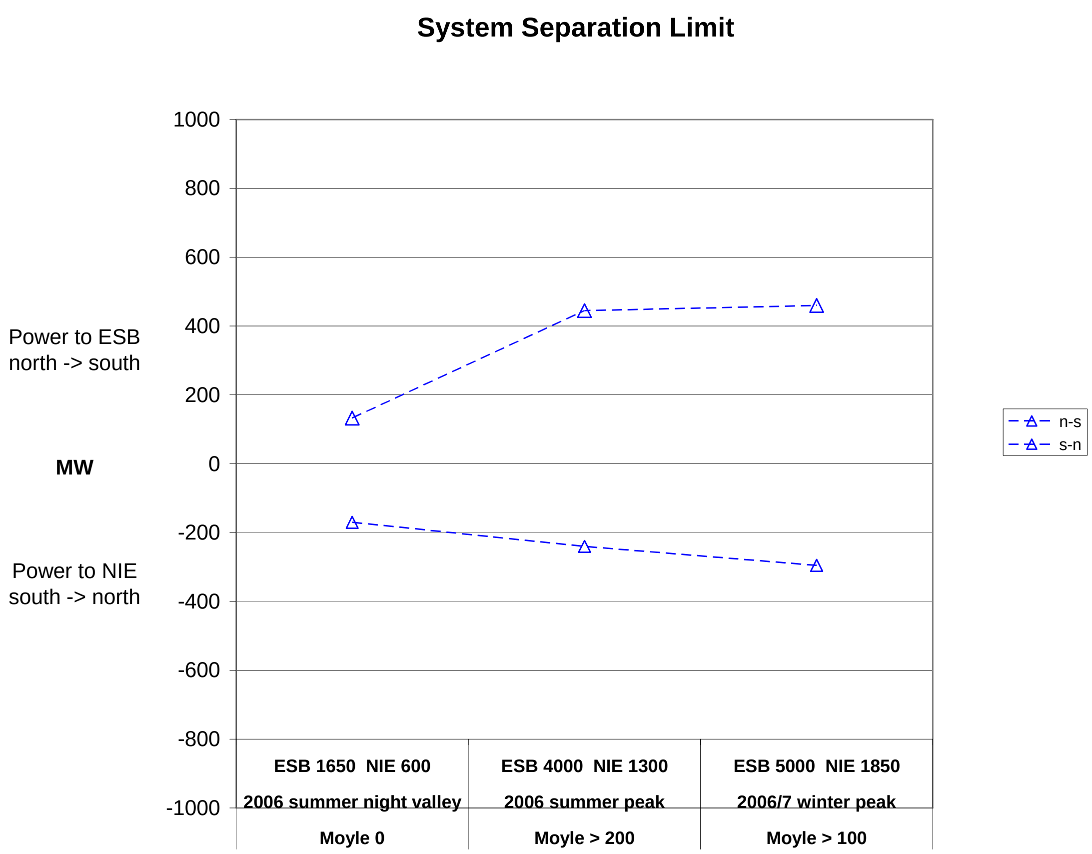
4. The green figures are the pre-separation power transfer from Scotland to Northern Ireland.
   These improve the ability of the Northern Ireland system to export power to Republic of Ireland. It is presumed that Northern Ireland is always importing power from Scotland

A graphical presentation of the system separation limits (for a selection of Moyle trades) is as follows.



In the above graph, power flow from north to south (to Republic of Ireland) is shown as a positive value and power flow from south to north (to Northern Ireland) is shown as a negative value. The values are plotted for three system conditions: winter peak, summer peak and summer night valley.

The red lines represent the capabilities of the Northern Ireland system and the green lines represent the capability of the Republic of Ireland system. There are three red lines for power to Republic of Ireland, showing the Northern Ireland export limit for three values of pre-contingency power flow on the DC link to Scotland.



The graph above shows normal separation limits in both directions.

The limits are correct provided the power import from Scotland to Northern Ireland is 0MW at summer night valley, is greater than 200MW for summer peak and is greater than 100MW at winter peak.

3.5 System Separation Conclusion

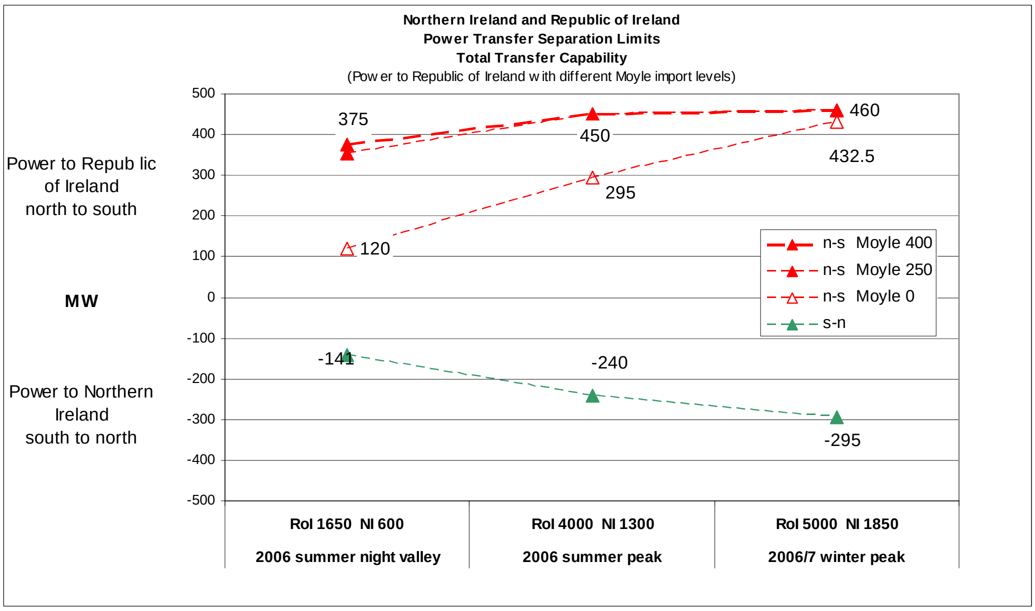
System separation must be considered when operating the system because the loss of a double circuit is a credible contingency.

System separation is a significant factor in evaluating power transfer capability in both directions. With the existing network, larger power transfers cannot be allowed because if a system separation occurs, the resulting power imbalances will cause unacceptably severe shocks to both transmission systems.

With a Moyle run-back scheme, the ability of Northern Ireland to export power to the Republic is enhanced, but still the system separation limit acts to limit power transfer in both directions.

A key factor here is that the power transfers considered are large in comparison with the size of both networks.

The calculations performed in this section used relatively benign assumptions about generator performance and about the quantity of non-responsive generation connected to the system. If these assumptions prove inaccurate, then the system separation power transfer limits may need to be revised. The expected system separation transfer limits for 2006/7 are shown below.



4 Loadflow

An analysis of interconnection capability between Republic of Ireland and Northern Ireland is not restricted to those circuits which actually cross the border. It is equally important to determine whether the combined transmission systems are capable of handling the power transfers. The results and findings of the technical studies as they relate to power transfer on the combined Republic of Ireland and Northern Ireland transmission system are documented in this section of the report. This chapter highlights a number of transmission constraints which limit power transfer between Republic of Ireland and Northern Ireland and which are located within the respective transmission systems.

A broad description of the existing Republic of Ireland and Northern Ireland transmission systems is presented. This is accompanied by a general overview of the method used in this report to calculate transfer capability.

Those transmission constraints that limit power transfers are discussed. It appears that a combination of additional cross-border interconnection with internal reinforcements will be required in order to maximise total Republic of Ireland Northern Ireland transfer capability. The Republic of Ireland system, for the studies that were performed in 2002, is not capable of transferring much power from Dublin to the north. In addition to an additional interconnection, the studies show that the Northern Ireland system may also require reinforcement but only to facilitate very large trades to the south. A large SVC in the Belfast area may be required.

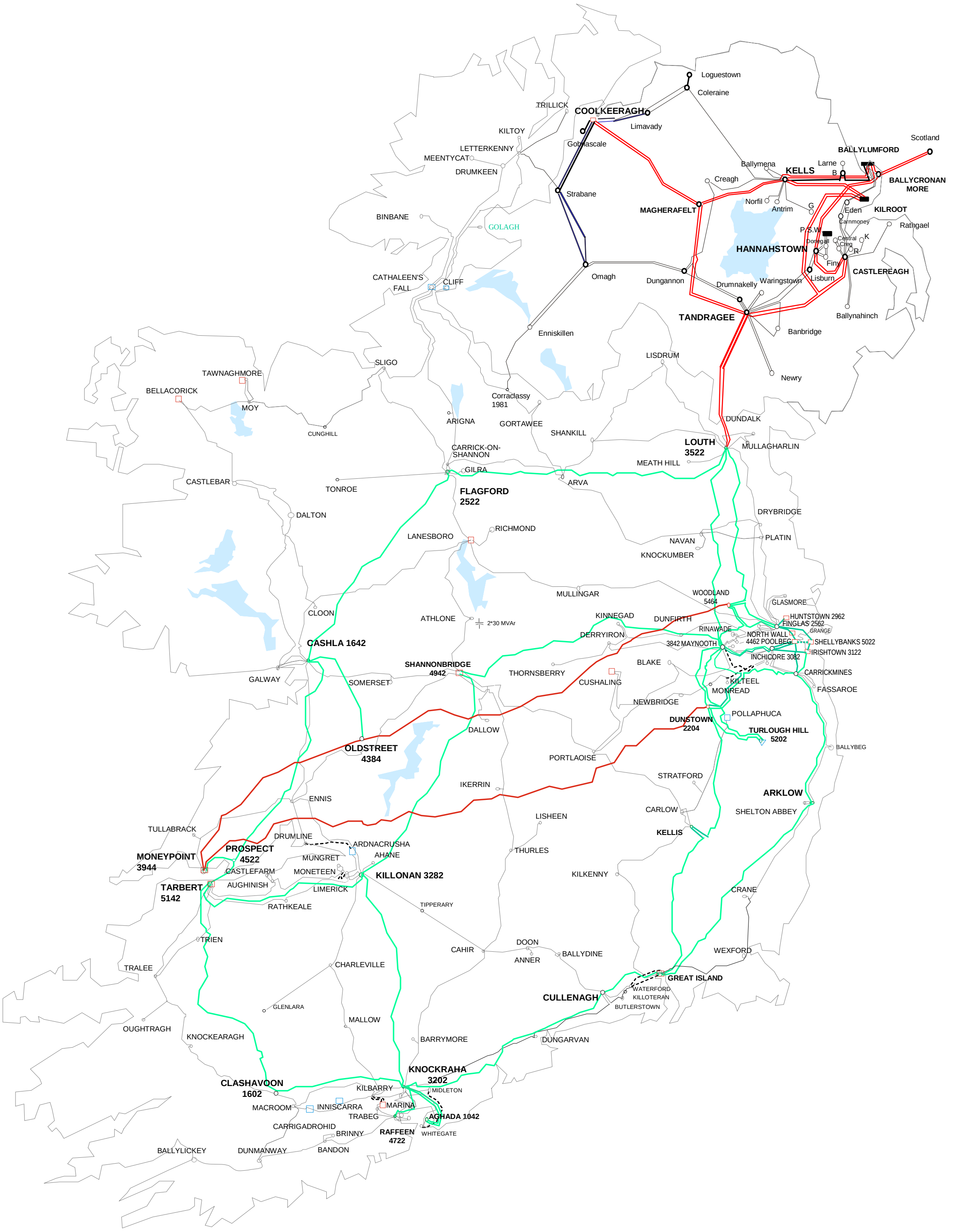
Another important consideration in evaluating significant transmission investments is whether the benefits of the project are likely to last. Correspondingly, the findings are presented of an analysis which is performed on a later year. Since the electricity growth rates on the Irish networks are high, this corresponds to significantly higher load conditions and illustrates the durability of the proposed interconnector development options.

The above considerations are concerned solely with the impact of single contingencies on an intact transmission network (including double circuit contingencies). The impact of transmission maintenance on available transfer capability is discussed in section 5.

4.1 Existing System

The Northern Ireland electricity transmission network consists of 275kV double circuits and 110kV single and double circuits. The Republic of Ireland transmission network consists of single circuits of 400kV, 220kV and 110kV.

The main interconnection between Northern Ireland and the Republic of Ireland is the Louth Tandragee 275kV double circuit. There are also two 110kV interconnections; Letterkenny Strabane 110kV and Corraclassy Enniskillen 110kV.



On stability grounds, the two 110kV interconnectors on their own, in the absence of the 275kV double circuit, are not sufficiently strong to join the two systems. Therefore, at present, if the 275kV double circuit trips, a remedial action scheme is in place that also trips the 110kV interconnections.[5] A perceived benefit of an additional interconnection is that this remedial action scheme could be disabled.

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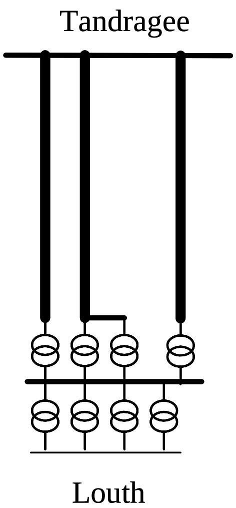
[5] This scheme also sends a run back signal to the Moyle DC interconnection between Northern Ireland and Scotland.

4.2 Power Wheeling

The performance of the combined power system is examined with all circuits in place. The power flow and loss reduction for the intact network are investigated.

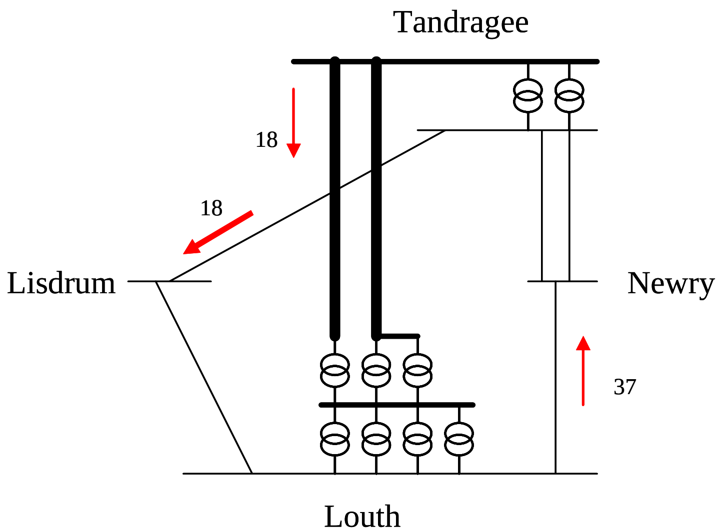
The different interconnector options will result in different base case power flows. Differing system impedances may cause power to flow out of one area, transfer through the other area and back to the first. These power flows might be referred to as power wheeling. The base case power flows are investigated for the different interconnector development options. A study is performed on the 2006/7 winter peak cases. In each case there is zero net power transfer between Ireland and Northern Ireland. An assessment of the loss reduction associated with these power flows is also performed.

Louth Tandragee 275kV circuit 3



A third Louth Tandragee 275kV interconnector has no impact on the base case power flows. Consequently, at zero power transfer, there is no change in system power flows and no saving in system losses.

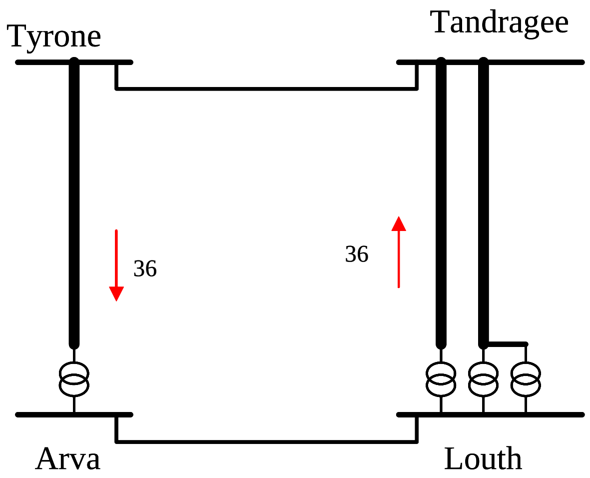
Multiple 110kV interconnector – no phase shifting transformer (PST)



A 110kV interconnector project (with no phase shifter transformers on the Tandragee Lisdrum 110kV and Newry Louth 110kV circuits) would result in the power flows shown above. This local reorganisation of the power flows is worth a 1.8 MW reduction in losses at 2006 / 7 winter peak. This loss reduction is achieved by rebalancing the loading on heavily loaded 110kV lines; Tandragee Newry 110 and Louth Lisdrum 110 and Louth Shankill 110.

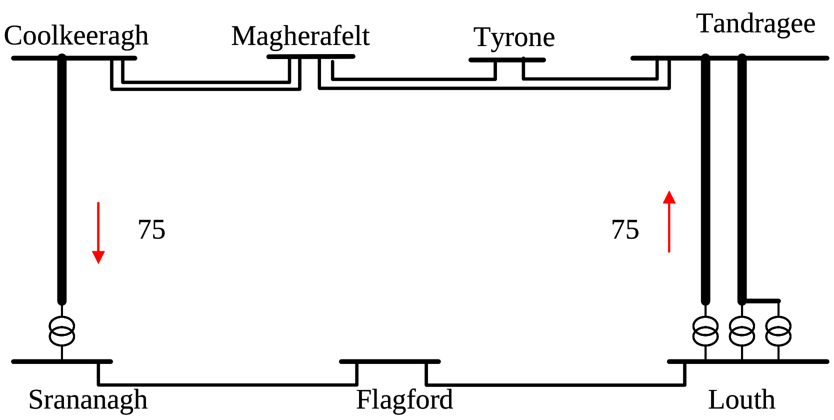
The option of a multiple 110kV interconnection with phase shift transformers is also studied. On the assumption that all phase shift transformers on the 110kV circuits are set to control flow on the 110kV circuits to zero, there is no change in flows on the two networks and no associated loss reduction.

Arva Tyrone 275kV



The Arva Tyrone 275kV project results in the following redistribution of power flows. The losses savings associated with this are 0.6 MW.

Coolkeeragh Srananagh 275kV



The proximity of Coolkeeragh generation station on one side of the border and the load in Donegal on the other side means that power flows will be as shown above.

The power flows result in a losses saving of 6.6 MW at 2006/7 winter peak, due mainly to the reduced loading on several 110kV circuits in the Republic of Ireland. The 75 MW flowing into Srananagh reduces the loading on the Republic of Ireland 220kV and 110kV network which have higher impedances than the Northern Ireland 275kV network.

This flow through the Northern Ireland system would have implications for the Northern Ireland transmission system. In particular, contingencies involving the loss of the Coolkeeragh Magherafelt 275kV double circuit would be affected. The 75 MW injection at Srananagh would also have implications for the Republic of Ireland transmission system. These would be largely positive.

Value of Losses

For a simplistic set of assumptions, the loss reductions might be valued as follows:-

- Energy Value:- €40 / MWh
- Annual loss factor (estimated): - 0.4
- No. of hours in a year:- 8760

On the basis of these assumptions, every MW is worth approx €140,000 per annum. Then, the annual benefit in loss reduction would be as follows.

	Zero net transfer loss reduction	Approximate Value per annum
Louth Tandragee circuit 3	0 MW	0
110kV Reinforcements (no PST)	1.8 MW	€250,000
Arva Tyrone 275	0.6 MW	€ 84,000
Coolkeeragh Srananagh 275	6.6 MW	€925,000

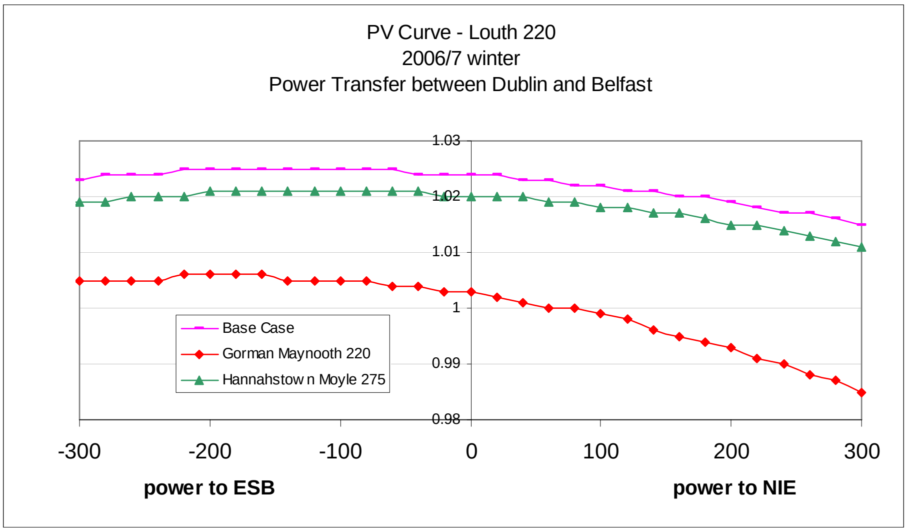
4.3 MVAr and Voltage

The performance of the combined power system is examined with all circuits in place. The variation in voltage with power transfer at important locations and the variation in system MVAr demand are investigated for the intact system.

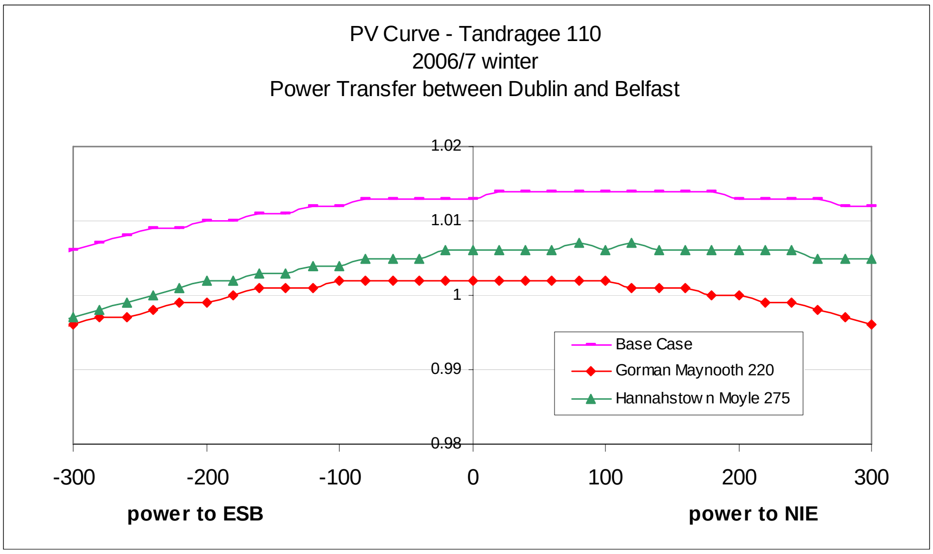
Experience from this study suggests that the voltage performance of the combined system is better during power transfers to Republic of Ireland than for power transfers to Northern Ireland.

A look at the voltage performance of buses on either system for a transfer of 300 MW in either direction illustrates this point. The figure below shows the voltage at Louth 220kV bus plotted against interconnector power flow for three scenarios. These are for an intact network, the loss of Gorman Maynooth 220 and the loss of Hannahstown Moyle 275kV single circuit.

The Louth 220kV voltage decreases with power transfer to Northern Ireland and is quite low in one post-contingency case for a 300 MW transfer (Gorman Maynooth 220kV for power flow to Northern Ireland).



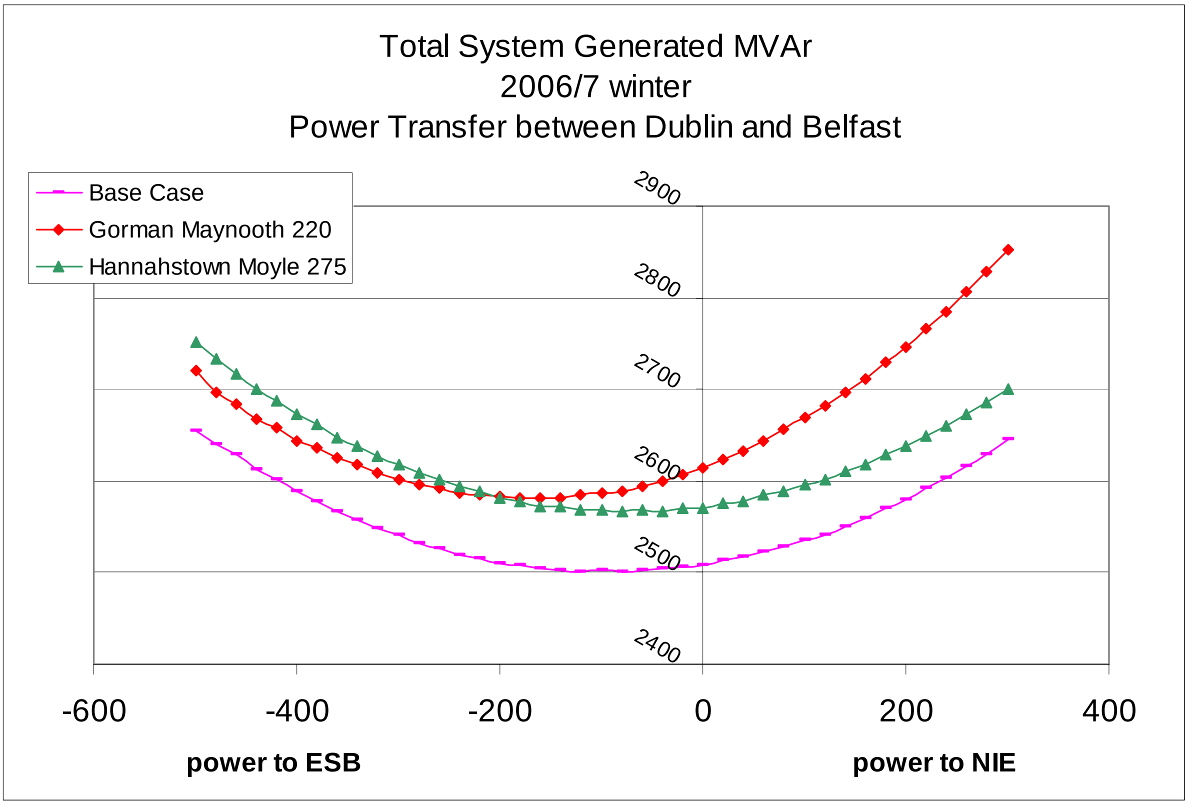
On the other hand, the voltages on the Northern Ireland system appear to be more robust than on the Republic of Ireland system. The Tandragee 110kV voltage appears to decrease less severely than the Louth 220kV case for the contingencies studied.



It appears that for moderate changes, for the importing system voltages benefit from the power import. This makes sense since the exporting system will have increased power flows and the importing system will have reduced power flows. There may be limits to this conclusion.

Current practice on the Republic of Ireland / Northern Ireland joint system is close to zero MVAr transfer. This practice may be unnecessarily harsh on the exporting system and may result in an imbalance in the provision of MVAr. Perhaps the system that is importing the power should concede a few MVAr in return for the MW, thus helping to even the voltage profile on the overall system.

While this conclusion is interesting, it is not clear from the above PV curves whether any significant voltage benefits exist for power transfer in one direction as opposed to the other. To illustrate this important point, traces of the total system MVAr demand are investigated. A trace of the generated MVAr total for the different power transfers is shown below.



For an intact network, it can be seen that the system MVAr demand actually reduces for the first 200 MW power transfer to Republic of Ireland. Thereafter the MVAr demand increases with power transfer to Republic of Ireland. The above graphs are calculated for the 2006/7 winter case. This graph is important because it shows why voltage problems would be more severe for power transfer to Northern Ireland than for power transfer to Republic of Ireland. This could be seen as one factor in determining natural flow for a given network topology.

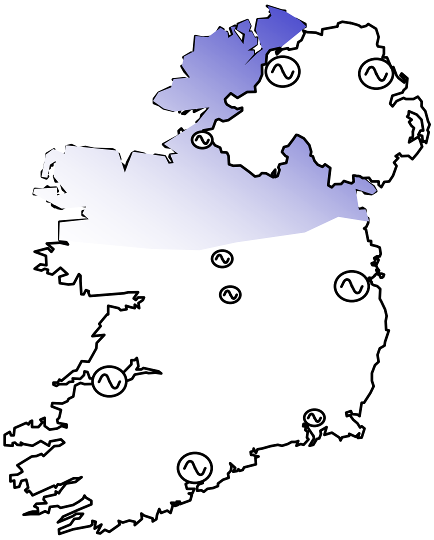
The graph also shows how quickly the system MVAr demand increases with a change in power transfer or for the loss of an important transmission circuit. At a 200MW transfer from Republic of Ireland to Northern Ireland, the loss of one 220kV line increases total MVAr demand by 180MVAr . Without this line, an increase in transfer from 200MW to 300MW now increases total MVAr demand by 100MVAr. This is twice as much as for the intact network where a similar increase in power transfer increased total MVAr demand by only 50MVAr.

There are large MVAr demand implications associated with large power transfers to Northern Ireland. No optimisation studies have been carried out to determine the position or level of dynamic reactive compensation that might offset this.

In other words, it appears to be less onerous in terms of reactive power demand for generation on the Northern Ireland system to supply load in the northern half of the Northern

Ireland system than for generation on the Republic of Ireland system to do so. A number of factors are at play here.

Geographical Proximity. Northern Ireland generation is geographically closer to some load on the Republic of Ireland system than any non-wind generation on the Republic of Ireland system. The shaded region below shows load on the Republic of Ireland system that might be considered geographically and electrically close to Northern Ireland generation.



Highly loaded lines. When Northern Ireland supplies power to Republic of Ireland, this reduces the loading on circuits on the Republic of Ireland 110kV system which are very highly loaded. When the Republic of Ireland supplies power to Northern Ireland, this increases the loading on those Republic of Ireland lines that are already highly loaded.

Line impedances. The Northern Ireland 275kV system consists of double circuits with twin bundle conductor with a cross section of approximately 500 mm^2. The Republic of Ireland 220kV system consists of single circuits with single bundle conductor with a cross section of 600mm^2. The relative per unit impedances per km of the transmission circuits are vastly different. The Republic of Ireland circuits have high impedance relative to the Northern Ireland circuits. This means that voltage drops are larger for large power transfers in the Republic of Ireland, i.e. for power transfers to Northern Ireland.

Unresponsive reducing MVAr. There is a lot of capacitance on the Republic of Ireland system which is designed to maintain steady state voltage conditions. An issue is that the quantity of capacitors is designed for the needs of the Republic of Ireland system at zero power transfer. More reactive power may be required to support large power transfers to Northern Ireland.

The voltage support provided by fixed capacitors depends on the voltage being healthy. If the voltage dips severely for any reason such as during a fault, then there may not be sufficient MVAr for the voltage to recover. Additionally, licence standards require both utilities to limit the step change in voltage between an intact network and a network immediately after a circuit is outaged. Increasing the amount of fixed capacitance can worsen the step change. An automatically adjusting source of reactive MVAr, such as a large SVC may be required.

4.4 Data and Methodology

Study Cases

For load analysis, four basic system load scenarios years were selected for study. These are 2006 summer, 2006/7 winter and 2011 summer, 2011/12 winter. They correspond to a medium term view and a long term view of network development.

The transmission networks are likely to develop between now and 2006/7. Both Republic of Ireland and Northern Ireland have internal approvals for a number of projects that are likely to be commissioned by 2006. The approved projects were all included in the 2006/7 studies, forming the "**Basecase**" models.

Once the studies began, it became clear that even with the addition of those projects which had capital approval by 2006, there might be some benefit to considering the impact of a limited number of additional reinforcements. For this purpose, a second 2006 set of cases is created including this limited number of additional reinforcements. This set forms the "**Basecase+**" models.

The "basecase" studies provide an insight into the capability of the joint network including only those projects with existing capital approvals. The "basecase+" studies highlight the benefit of internal system reinforcements on both networks. The studies were designed to identify the underlying strength of the respective transmission systems and to examine the impact of major reinforcement on both networks of the available transfer capacity.

The projects added to the "basecase+" studies are as follows:-

Northern Ireland

- Tyrone 275kV station – replace proposed 120 MVA transformer with a 240 MVA transformer.
- Large SVC at Castlereagh
- Uprate Omagh Strabane both 110kV lines to UPAS 166 / 145 MVA.
- Uprate Omagh Enniskillen both 110kV lines to 126 / 109 MVA.

Republic of Ireland

- Add a Corduff Louth 220kV circuit.
- Add a third Corduff Finglas 220kV circuit.
- Add an Athlone Shannonbridge second 110kV circuit.
- Uprate Cathaleen's Fall – Letterkenny 110kV line to 126 / 107 MVA.
- Uprate Cathaleen's Fall – Golagh 110kV line to 126 / 107 MVA.
- Uprate Cashla Cloon 110kV line to 164 / 137 MVA.
- Uprate Cashla Ennis 110kV line to 126 / 107 MVA.
- Replace the Cashla 175 MVA 220 / 110kV transformer with a 250 MVA transformer.

The 2011/12 studies were performed with the same reinforcements as above. However, additional reinforcements were also required to cater for load growth on the Republic of

Ireland and Northern Ireland systems. The additional reinforcements needed for the 2011/12 studies are as follows.

Northern Ireland

- Provide a 110kV busbar at Drumkee 275kV station and loop local 110kV circuits into the station.[6]
- Add a 20 MVAr Coleraine 110kV shunt capacitor.

Republic of Ireland

- Killonan replace the two 63 MVA 220 / 110kV transformers so that Killonan is a three by 125 MVA transformer station.
- Add a third Navan Gorman 110kV line.
- Uprate Carlow Kellis circuit 2 to 126 / 107 MVA.
- Replace the 125 MVA Srananagh 220 / 110kV transformer with a 250 MVA transformer.
- Add a third 250 MVA transformer at Maynooth.
- Add a 200 MVAr SVC at Flagford 220kV station.

Planning and Security Criteria

The Northern Ireland and Republic of Ireland systems are planned in accordance with specific planning and security criteria. In the case of Northern Ireland, adherence to planning and security standards forms part of their Licence obligations and this is outlined in the "Transmission and Distribution System Security and Planning Standards" document. In the case of Republic of Ireland, the system is planned to comply with the "Transmission Planning Criteria" document (adopted in 1998). The two sets of criteria are broadly similar, but are not identical.

For the purposes of the studies, a single harmonised set of planning criteria was agreed between Northern Ireland and Republic of Ireland. This is summarised below.

Voltage Criteria

For the purposes of this analysis, transfer capabilities are calculated assuming that for any contingency:-

- Minimum voltage shall not fall below 90% of nominal
- Maximum voltage shall not exceed 110% of nominal
- Step change on Northern Ireland system will not exceed 6% (10% for double circuit)
- Step change on Republic of Ireland system will not exceed 10%

Thermal Rating Criteria

For the purposes of this analysis, transfer capabilities are calculated assuming that for any contingency:-

- No temporary overloads are allowed on transmission lines.
- A post contingency temporary overload of 10% is permitted on system transformers.
- Dublin cables have temporary overload capability.

[6] Northern Ireland Electricity may also include an additional inter-bus transformer at this station.

Contingency Set

The loadflow studies involve not only a consideration of the healthy system, but also the impact of credible planned and unplanned outage conditions. For this analysis, the set of credible outage contingency events is defined as follows:-

- At **winter peak** loads, the planning and security criteria should be met for the unplanned outage of any single item of generation or transmission equipment occur; (N -1) (N-G-1) (N-DCT).

- At **summer peak**, the planning and security criteria should not be violated should any item of plant be out of service due to a planned outage and an unplanned outage of any single item of generation or transmission equipment occur; (N -1, N-1-1).

- **At summer minimum**, the planning and security criteria should not be violated should an unplanned outage of any single item of generation or transmission equipment occur; (N -1) (N-G-1). [7]

In any season, the planning and security criteria should not be violated should an unplanned outage of any double circuit 275 kV transmission line (conductors all on the same tower, DCT) occur on the Northern Ireland network; (winter: N-DCT, summer: N - DCT).

This criterion presumes a co-ordinated maintenance programme between Republic of Ireland and Northern Ireland.

Winter	N-1	N-G-1	N-DCT[8]	
Summer	N-1	N-G-1	N-DCT	N-1-1
Summer Min	N-1	N-G-1		
Not designing to withstand				
Winter	*N-G-DCT*[9]			
Summer	*N-G-DCT*	*N-1-DCT*	.	

For the summer night valley (summer minimum) cases, the joint transmission system is tested only for moderate power transfers. This decision was based on the assumption that both systems would require local generation to share as much of the load as possible, which would leave little room for importing power on either system.

Modelling Generator Outages

Contingencies involving the loss of a large generator need careful consideration to ensure that results remain compatible regardless of where in the model the swing generator is

[7] N-1-1 was not studied for summer night valley. At summer night valley, N-1-1 studies are usually performed to calculate generator exit capacity from a particular node. This study is concerned with the strength of the backbone system.

[8] DCT = Double Circuit Tower

[9] Internal NIE debate on this at present.

located. A generator trip in a loadflow study causes the swing bus to pick up the deficit of generation and therefore the location of the swing bus is significant.

On the real transmission system, reserve is shared over a number of generators on both systems. The current practice is that Republic of Ireland and Northern Ireland share the provision of reserve in ratio 2:1.

For loadflow studies, the loss of a generator is 100% covered by the swing bus. For these studies, the method employed is for Republic of Ireland pick up 66% and Northern Ireland pick up 33% of the generation that has tripped. For the loss of a 400MW set, Republic of Ireland would therefore pick up 266MW, and Northern Ireland 133MW.

This approach ensures that a common definition of transfer is used for all contingencies and that a common post-contingency power transfer is achieved regardless of which side of the border the swing generator bus is located.

Treatment of Radial Circuits

By 2011 summer and 2011/12 winter it can be expected that the loadings on some radial circuits may increase due to natural load growth. Line overloads on these circuits, or associated voltage problems on radial circuits or problems in other parts of the network, that are not associated with power transfers between Ireland and Northern Ireland are not included in this report.

Treatment of Double Circuit Contingencies

Whether the loss of a double circuit as a single contingency is treated as a more credible contingency or as a less credible contingency effectively determines the transfer capability available on a transmission system.

The compromise reached for the studies is that the system is tested for the loss of a 275kV double circuit when there is no maintenance on the transmission system. And the system is not tested for the loss of a 275kV double circuit when there is maintenance on the transmission system or when local generation is not running (a less credible outage).

The system is not tested for the loss of a 220kV double circuit.

This approach reflects the methods currently used on the Northern Ireland and Republic of Ireland transmission systems respectively.

Reliability of Double Circuits

An overview of the reliability of the double circuits on the joint transmission system is provided below.

The entire Northern Ireland 275kV network consists of 275kV double circuits. A number of 275kV double circuits have tripped in recent years.

A recent double circuit trip from Ballylumford was due to lightning strikes.

Some work, in terms of de-spacing the conductors, was done more than 10 years ago on the Coolkeeragh Magherafelt 275kV double circuit to improve its reliability. There is on-going monitoring of the condition of the insulators and conductors and necessary work is deemed a priority to maintain the reliability of this double circuit.

Nevertheless, a 275kV double circuit lightning related trip occurred in summer 2004 in Northern Ireland. There has also been a recent 220kV double circuit lightning related trip in the Republic of Ireland.

If the loss of a Northern Ireland double circuit could lead to a situation where the system is in danger of blackout, then Northern Ireland use remedial action schemes to ‘box’ this event in. Examples of remedial actions used are generator run-back, load shed, inter-trip and re-supply schemes. Other trips have been due to protection maloperation.

In the 1970s, the Louth Tandragee 275kV double circuit interconnector had a poor record of reliability due to malicious damage. However, the double circuit has not tripped as a single contingency since being recommissioned in 1995.

There are a number of 220kV double circuits on the Republic of Ireland network. These have not dominated transmission reinforcement decisions in the past. This may be due to the fact that these 220kV double circuits have not tripped as often as Northern Ireland 275kV double circuits.

The difference in perceived reliability may be due to the longer length of double circuit on the Northern Ireland system.

Remedial Action Schemes

At present, the Republic of Ireland transmission planning criteria allow remedial action schemes to be used to cover delays in reinforcements. There are a number of remedial action schemes currently in use on the Republic of Ireland transmission system. There are also a number of remedial action schemes on the Northern Ireland transmission system. Both system operators are satisfied to have a remedial action scheme monitoring the Louth Tandragee 275kV double circuit.

Some of the studies performed for this report include the impact of remedial action schemes and some do not. Presenting the results of studies, which were carried out while ignoring any Remedial Action Schemes, identifies the inherent strengths and weaknesses on the intact transmission system. While this result is extremely valuable, this analysis may lead to a low transfer capability.

Reasons why a remedial action scheme might become unacceptable include stability issues on operation of the remedial action scheme at very high transfers or a fear that a remedial action scheme had become unacceptably complex.

The remedial action schemes of interest for the studies are as follows:

For the loss of Louth Tandragee 275kV double circuit, an intertrip signal is sent to the two 110kV interconnections - the Letterkenny - Strabane 110kV line and the Enniskillen - Corraclassy 110kV line and a signal is also sent to the Moyle DC link to adjust import level.

During periods of high generation and low load at Coolkeeragh, the loss of Coolkeeragh Magherafelt 275kV double circuit will overload a number of circuits; Coolkeeragh Strabane 110 (even with three circuits), Coolkeeragh Coleraine 110, Coolkeeragh Limavady 110 and Coleraine Kells 110. A remedial action scheme will run back Coolkeeragh 400 MW unit to 170 MW to prevent overloads.

During periods of low generation and high load at Coolkeeragh, the loss of Coolkeeragh Magherafelt 275kV double circuit could result in low voltage at Coolkeeragh, and to guard against this is an undervoltage load shedding scheme is installed at Coolkeeragh.

In winter, the loss of one of the Tandragee Drumnakelly 110kV circuits can result in overloads on the remaining parallel circuits. In summer, a maintenance and trip combination of two Tandragee Drumnakelly 110kV circuits may overload the remaining parallel circuit. A remedial action scheme in Drumnakelly manages these overloads by opening one or both of the Drumnakelly Dungannon 110kV circuits.

Transfer Scenarios

The transfer scenarios in this study are chosen to test known system limitations. Understanding of the limitations is based on experience with the existing system and previous studies.

The expected system bottlenecks are shown in the figure on the next page. For the purpose of the Republic of Ireland / Northern Ireland studies, generation is grouped depending on its location relative to the bottlenecks. Several generation groups have been identified. The generation groups are as follows:-

1 Coolkeeragh
2 Belfast – Ballylumford, Moyle, Kilroot
3 Dublin
4 South
5 Shannon – Tarbert, Moneypoint3, Ardnacrusha
6 Cashla

Transfer Scenarios are chosen that stress the network in a number of different directions. Therefore, the study results are robust. The objective is to investigate the transfer levels that stress the particular interconnections and internal boundaries.

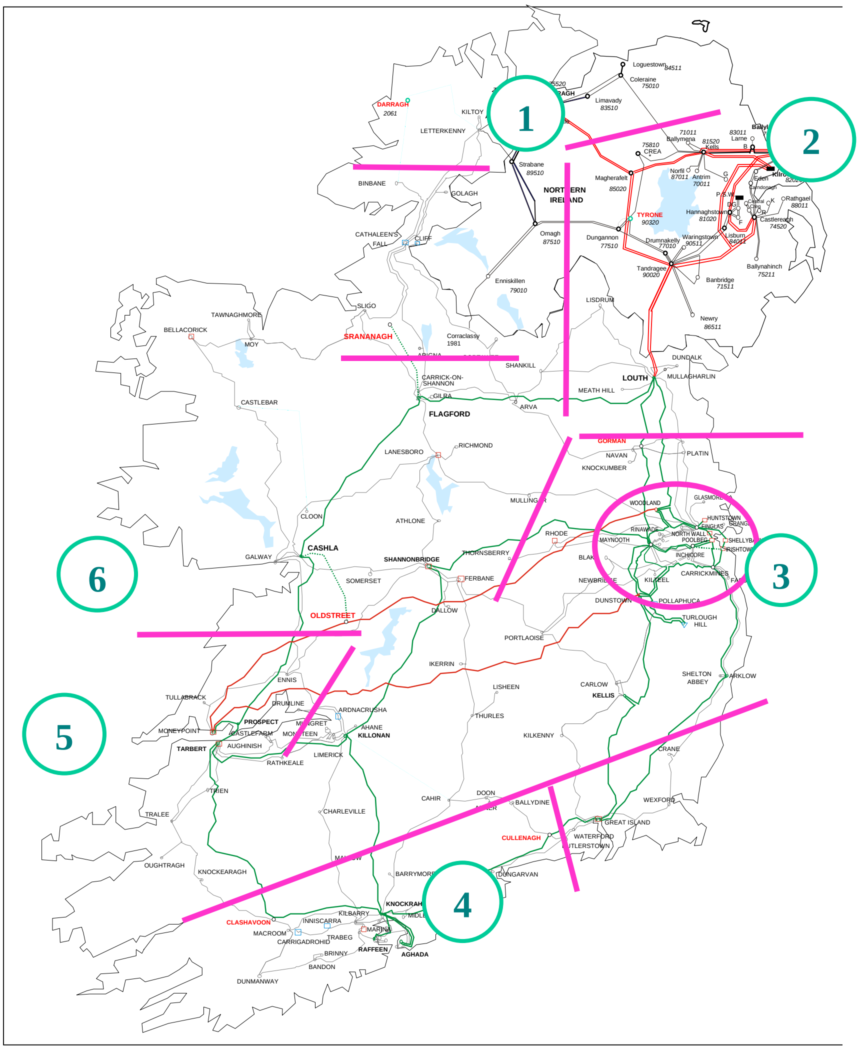
For the studies the extreme south of Ireland (area 4) is not being considered. Additionally, studies which reasonably can be expected to stress the same internal boundaries do not need to be duplicated. The number of options is reduced to 8, as shown.

From NI to RoI — **Power Transfer Scenario**

NI	RoI	
Increase at Kilroot, Kells	Reduce at Dublin	2-3
Increase at Coolkeeragh		1-3
Increase at Kilroot, Kells	Reduce at Shannon	2-5
Increase at Coolkeeragh		1-5

From RoI to NI — **Power Transfer Scenario**

NI	RoI	
Reduce at Kilroot, Moyle, Ballylumford	Increase at Dublin	3-2
	Increase in Cashla	6-2
Reduce at Coolkeeragh	Increase at Dublin	3-1
	Increase at Shannon	5-1



Credibility of Transfer Scenarios

Some of the transfer scenarios are more likely to occur and therefore to be more important to all Ireland energy trading than others. A discussion of the energy outlook for the areas involved is as follows.

Belfast
Existing Sites – Kilroot, Ballylumford and Moyle.
Potential Site - Kells
There is new generation recently commissioned at Ballylumford; there is new interconnection at Moyle and there is space at Kilroot for additional generation. There is also the possibility of generation locating close to Kells. In the short term, it appears likely that a generation capacity shortfall on the Republic of Ireland system will be met from this area. It is therefore very important to evaluate the ability of the joint transmission system to get power from this area to Republic of Ireland.

As regards power flow in the opposite direction, Belfast is a large load centre. While there is a lot of generation in the area, combinations of generator outages and unexpected reduction in power from the DC link to Scotland make it important that the joint transmission system be able supply power from Republic of Ireland to Northern Ireland. In the future, there may also be an economic case for sourcing power in the Republic of Ireland for export to Scotland via the existing DC link.

Coolkeeragh
Existing site- Coolkeeragh
Potential site – Offshore wind
The gas pipeline to Derry is sized close to the present demand and therefore there is unlikely to be significant additional thermal generation after the commissioning of the new 400 MW unit at Coolkeeragh. The wind resource in the north west is very significant with a large number of expressions of interest in constructing windfarms in the area. It is therefore important to evaluate the ability of the joint transmission system to export power away from Coolkeeragh.

The Coolkeeragh main plant is a single 400 MW unit. Therefore, when this unit is out for maintenance the Derry load will have to be supplied from elsewhere. It is important to evaluate the ability of the joint transmission system to provide power to meet the north west load. The load in the north west of Northern Ireland is approx *400 MW* for the 2006 winter peak.

Dublin
Existing site – Poolbeg (including Shellybanks), Huntstown, Dublin Bay Power (Irishtown), North Wall, Turlough Hill.

Potential Sites – Dublin already has excess generation relative to its load and has potential for exporting power. In addition to new generation at Huntstown and Dublin Bay Power, there are several expressions of interest for increased generation near Dublin. The studies used Maynooth because it is on the Dublin 220kV network and is unlikely to exacerbate loadings on the Dublin 220kV cable network.

Related sites – For the purposes of the studies, power transfer to or from Northern Ireland involving generation south of Dublin [Great Island, Marina, Aghada] can be considered as routed via Dublin.

In the short term, in the event of a requirement for power transfer to Northern Ireland, it is likely that this power would be supplied from the Dublin area.

As regards power flow to the Republic of Ireland, this is likely to be one of the dominant power destinations or routes. Dublin is a large load centre. It is also strongly connected via two 220kV circuits and two 110kV circuits to the interconnection point with Northern Ireland. Consequently, most of the power transfers with Northern Ireland, both import and export, effectively travel on the Louth to Dublin 220kV corridor.

Shannon and Cashla[10]
Existing sites – Moneypoint, Tarbert, Ardnacrusha
Potential site - Cashla
Import to the Area
Changes in the running regime at Ardnacrusha mean that its availability is less predictable than before. It is unlikely that additional generation will locate at Ardnacrusha.

Of the existing generation on the Republic of Ireland system, Tarbert is relatively low in the running order.

The Moneypoint units are quite low cost but currently generate a large quantity of greenhouse gases. These units are likely to need refurbishment to reduce their output of these gases. There is a credible case for examining the ability of the joint transmission network to import power to Shannon. This could be necessary for economic dispatch, generator maintenance or potential generator retirement reasons.

Export from the area
This would require the construction of new generation to consider supplying significant quantities of power from this area to Northern Ireland. The gas pipeline that is currently being brought via Limerick to Cashla means that there is fuel for additional generation to locate in this area. A commercial gas find off the Mayo coast would increases the possibility of generation locating here on the west of the Republic of Ireland network, but a gas pipeline to bring this gas ashore has had difficulty in obtaining planning permission.

For power transfer to Northern Ireland, one of the studies has generation located at Cashla, the other has generation located at Killonan / Tarbert. This is done to examine the relative differences between locating generation in the two areas.

[10] Since the studies were completed, two large generators have decided to connect to the transmission system in the Republic of Ireland in this area. Tynagh, a 400 MW generator is to loop into the Cashla Oldstreet 220kV circuit. In addition, two 75MW generators are to connect at Aughinish Alumina which is between the existing sites at Ardnacrusha and Tarbert. While there may be some local issues associated with the exact locations chosen, the location of this generation in the area matches the sites selected in the report.

4.5 Transfer Capacity Increase

A large number of studies was performed to calculate the transfer capacity for a wide range of network conditions, reinforcement programmes, contingency types and interconnector development options.

- Network conditions (2006 / 7 winter, 2006 summer, 2011/12 winter and 2011 summer)
- Reinforcement programmes (Basecase and basecase+)
- Interconnector development options (none, 110kV, 110kV with phase shift transformers, 275kV Arva Tyrone and 275kV Coolkeeragh Srananagh)
- Contingency types (loss of single circuits are presented differently from loss of double circuits)

The findings of the studies show how a combination of additional cross-border interconnection with internal reinforcements is required in order to maximise transfer capability in each direction.

The findings of the studies also make it possible to compare the technical performance of the different interconnector development options.

4.5.1 2006/7 Result Summary

A large number of studies were performed to calculate the transfer capability for all the interconnector development options. These studies were performed for a wide range of power transfers and for both summer and winter cases. The suite of studies was performed initially with an approved reinforcement programme and then repeated with both the approved reinforcement programme and several additional reinforcements.

For the latter suite of studies, the further reinforcements (in addition to the approved reinforcements) are as follows:-

- Drumkee 275kV station – replace proposed 120 MVA transformer with a 240 MVA transformer.
- Large SVC at Castlereagh 275kV station
- Uprate Omagh Strabane both 110kV lines to UPAS 166 / 145 MVA.
- Uprate Omagh Enniskillen both 110kV lines to 126 / 109 MVA.

- Add a Corduff Louth 220kV circuit.
- Add a third Corduff Finglas 220kV circuit.
- Add an Athlone Shannonbridge second 110kV circuit.
- Uprate Cathaleen’s Fall – Letterkenny 110kV line to 126 / 107 MVA.
- Uprate Cathaleen’s Fall – Golagh 110kV line to 126 / 107 MVA.
- Uprate Cashla Cloon 110kV line to 164 / 137 MVA.
- Uprate Cashla Ennis 110kV line to 126 / 107 MVA.
- Replace the Cashla 175 MVA 220 / 110kV transformer with a 250 MVA transformer.

The studies make it possible to identify which interconnector provides the best technical performance. The purpose of an additional interconnection is to raise the transfer capability in both directions.

These results show that both a cross-border additional interconnector and internal reinforcements are required in order to achieve a large increase in transfer capability in both directions between Republic of Ireland and Northern Ireland.

Northern Ireland to Republic of Ireland – 2006/7 Winter

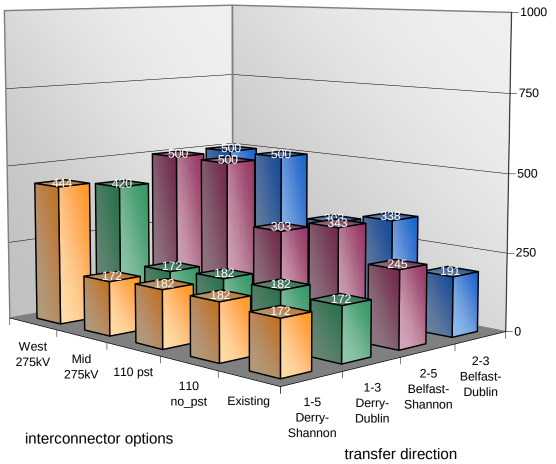
Results **Transfers from Northern Ireland to Republic of Ireland**

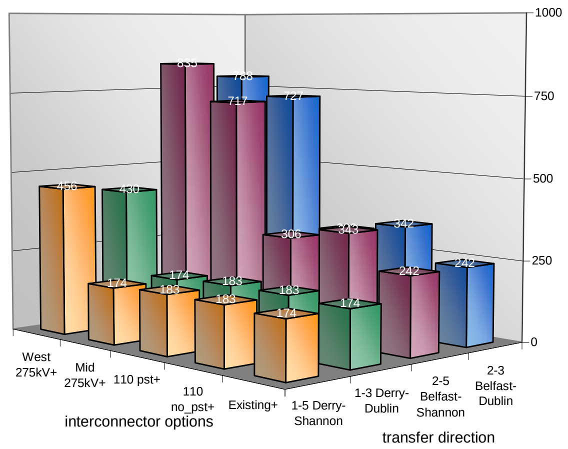
0607 Winter **Minimum of N-1 & N-DC**

Overall Limits

Approved Reinforcements

Approved Reinforcements + Additional Reinforcements





Overall Limits

		Existing	110 no_pst	110 pst	Mid 275kV	West 275kV
2-3	Belfast-Dublin	191	338	303	500	500
2-5	Belfast-Shannon	245	343	303	500	500
1-3	Derry-Dublin	172	182	182	172	420
1-5	Derry-Shannon	172	182	182	172	444

Key to Shading NIE Limit | I/C Limit | ESB Limit

Overall Limits

		Existing+	110 no_pst+	110 pst+	Mid 275kV+	West 275kV+
2-3	Belfast-Dublin	242	342	306	727	788
2-5	Belfast-Shannon	242	343	306	717	835
1-3	Derry-Dublin	174	183	183	174	430
1-5	Derry-Shannon	174	183	183	174	456

Key to Shading NIE Limit | I/C Limit | ESB Limit

Northern Ireland to Republic of Ireland – 2006 Summer

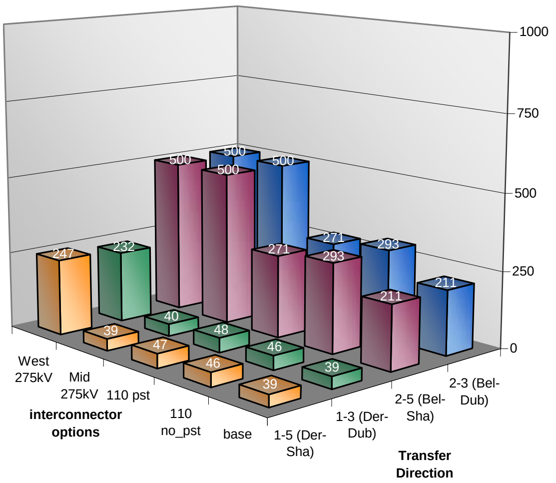
TLTG Results **Transfers from Northern Ireland to Republic of Ireland**

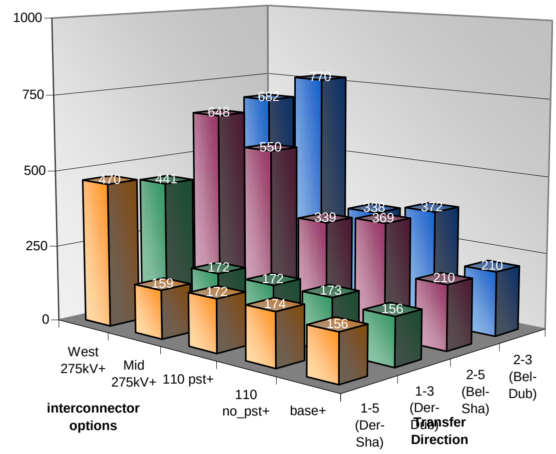
06 Summer **Minimum of N-1 & N-DC**

Overall Limits

Approved Reinforcements

Approved Reinforcements + Additional Reinforcements





Overall Limits

		base	110 no_pst	110 pst	Mid 275kV	West 275kV
2-3	Belfast-Dublin	211	293	271	500	500
2-5	Belfast-Shannon	211	293	271	500	500
1-3	Derry-Dublin	39	46	48	40	232
1-5	Derry-Shannon	39	46	47	39	247

Key to Shading NIE Limit | I/C Limit | ESB Limit

Overall Limits

		base+	110 no_pst+	110 pst+	Mid 275kV+	West 275kV+
2-3	Belfast-Dublin	210	372	338	770	682
2-5	Belfast-Shannon	210	369	339	550	648
1-3	Derry-Dublin	156	173	172	172	441
1-5	Derry-Shannon	156	174	172	159	470

Key to Shading NIE Limit | I/C Limit | ESB Limit

Power to Republic of Ireland – TLTG Results

The figures on the previous page show the power transfers that are achievable for the different scenarios. Appendix 1 contains more detail on the contingencies that limit the transfer capabilities for the 2006/7 winter case.

For power transfer to Republic of Ireland, the studies with only approved reinforcements show significant increases in transfer capability for some interconnector options. It is possible therefore to use these basecase results to compare the performance of the different interconnector options for power transfer to the Republic of Ireland.

110kV Options

The 110kV interconnector development options (each of which consists of multiple 110kV lines) do not match the performance of the 275kV interconnector development options

275kV Approach

Significant increases in the ability to transfer power from the Belfast area to the Republic of Ireland will result from either the Coolkeeragh Srananagh 275kV (west country 275kV) or Arva Tyrone 275kV (mid country 275kV) interconnection.

The west country option, Coolkeeragh Srananagh 275kV, is also successful at increasing the quantity of power that can be transferred from Coolkeeragh to the Republic of Ireland. The Arva Tyrone 275kV interconnector does not provide this benefit.

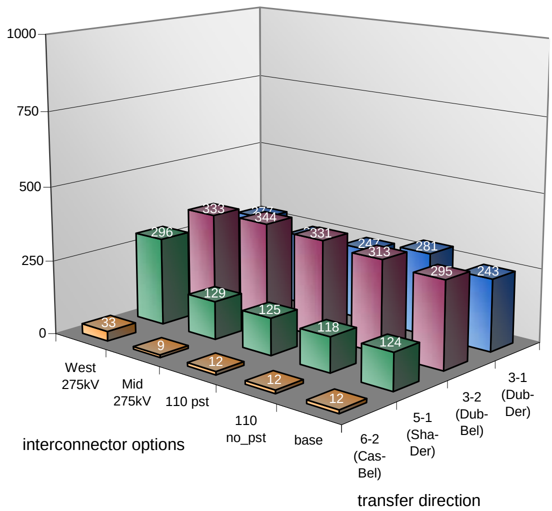
With either 275kV interconnection, there is a significant increase in transfer capability for power transfer to the Republic of Ireland even with only the approved set of reinforcements. It is only to facilitate power transfers in excess of 500 MW to the south that would require further internal reinforcement is required. This might consist of dynamic reactive reserve, such as a large SVC, on the Northern Ireland system.

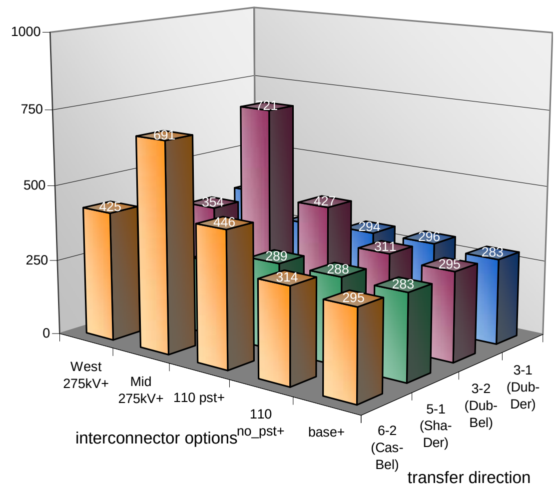
Republic of Ireland to Northern Ireland – 2006/7 Winter

TLTG Results **Transfers from Republic of Ireland to Northern Ireland**

0607 Winter **Minimum of N-1 & N-DC & Acceptable System Split** **Overall Limits**

Approved Reinforcements | **Approved Reinforcements + Additional Reinforcements**





Overall Limits

		base	110 no_pst	110 pst	Mid 275kV	West 275kV
3-1	Dublin-Derry	243	281	247	244	277
3-2	Dublin-Belfast	295	313	331	344	333
5-1	Shannon-Derry	124	118	125	129	296
6-2	Cashla-Belfast	12	12	12	9	33

Key to Shading NIE Limit | I/C Limit | ESB Limit

Overall Limits

		base+	110 no_pst+	110 pst+	Mid 275kV+	West 275kV+
3-1	Dublin-Derry	283	296	294	285	367
3-2	Dublin-Belfast	295	311	427	721	354
5-1	Shannon-Derry	283	288	289	248	257
6-2	Cashla-Belfast	295	314	446	691	425

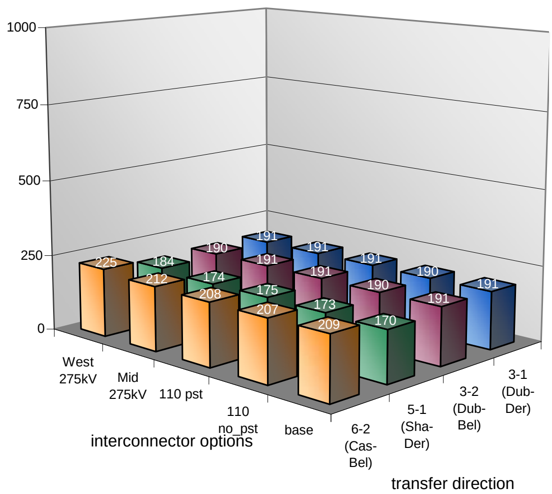
Key to Shading NIE Limit | I/C Limit | ESB Limit

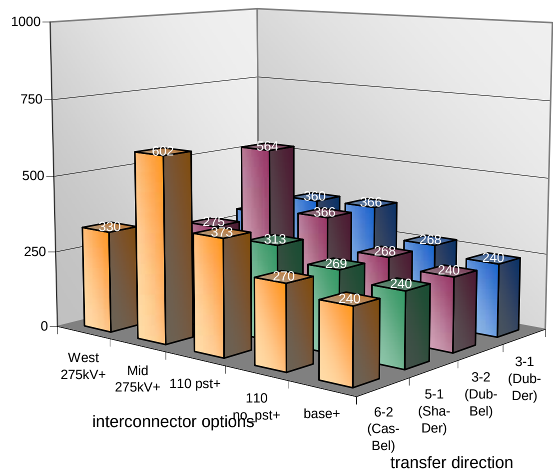
Republic of Ireland to Northern Ireland – 2006 Summer

TLTG Results **Transfers from Republic of Ireland to Northern Ireland**

06 Summer **Minimum of N-1 & N-DC & Acceptable System Split** **Overall Limits**

Approved Reinforcements | **Approved Reinforcements + Additional Reinforcements**





Overall Limits

		base	110a	110b	Mid 275kV	West 275kV
3-1	Dublin-Derry	191	190	191	191	191
3-2	Dublin-Belfast	191	190	191	191	190
5-1	Shannon-Derry	170	173	175	174	184
6-2	Cashla-Belfast	209	207	208	212	225

Key to Shading NIE Limit | I/C Limit | ESB Limit

Overall Limits

		base+	110a+	110b+	Mid 275kV+	West 275kV+
3-1	Dublin-Derry	240	268	366	360	289
3-2	Dublin-Belfast	240	268	366	564	275
5-1	Shannon-Derry	240	269	313	293	295
6-2	Cashla-Belfast	240	270	373	602	330

Key to Shading NIE Limit | I/C Limit | ESB Limit

Power to Northern Ireland – TLTG Results

The figures on the previous page show the power transfers that are achievable for the different scenarios. Appendix 1 contains more detail on the contingencies that limit the transfer capabilities for the 2006/7 winter case.

The system studies with approved reinforcements show only minor increases in power transfer capability to Northern Ireland. This is because the internal transmission networks are not capable of supporting the large power transfers to the interconnectors. The transfer restrictions are largely internal on the Republic of Ireland network.

In order to assess the performance of the interconnector options, it is necessary to examine the results of the studies which include both approved reinforcements and further reinforcements. These further reinforcements are necessary to gain the full benefit of additional interconnection in this direction.

For power transfer to Northern Ireland, the most significant internal reinforcement is the inclusion of a 220kV circuit from Dublin to Louth. This is important for all power transfer scenarios to Northern Ireland.

Some additional reinforcements are only relevant for a subset of transfer scenarios. For example, reinforcements in the west (Cashla transformers, uprate Cashla Cloon 110, uprate Cashla Ennis 110) and in the middle of the country (second Athlone Shannonbridge 110) are only required to facilitate increased power transfer from the west to Northern Ireland. Some other reinforcements are specific to the generation development assumptions used in the studies (third Corduff Finglas 220kV) and are not considered relevant to our interconnection studies.

Based on these studies, it is possible to compare the performance of the different interconnector options for power transfer to Northern Ireland.

110kV Results

The multi-line 110kV options do not offer a significant increase in transfer capability.

275kV Results

Comparing the two 275kV options, the key contingency is the loss of Louth Tandragee 275kV double circuit. With Coolkeeragh Srananagh 275kV, the 110kV network in the Republic of Ireland overloads at much lower power transfers than in the case for Arva Tyrone 275. Therefore, for power flows to Northern Ireland, Arva Tyrone 275kV gives superior technical performance.

4.5.2 Later Year

A series of studies was performed for a later year, 2011/12, to investigate how the potential interconnectors will perform at significantly higher load levels.

Growth in electricity demand in both Northern Ireland and the Republic of Ireland is high compared to the European average. To meet demand growth, a number of additional reinforcements had to be added. This allowed system planning standards to be met in the later year.

In addition to the base case+ reinforcements, the following additional reinforcements were used in the studies.

Northern Ireland
- Tyrone 110kV station plus replace existing 120 MVA transformer with 240 MVA IBT.
- Tyrone 25 MVAr capacitor
- Uprate Dungannon Tyrone 110kV circuits
- Coleraine 20 MVAr capacitor

Republic of Ireland
- Cashla replace existing 175 MVA transformer with 250 MVA transformer
- Killonan uprate to 3 * 125 MVA 220/110 transformer
- Navan Gorman 110kV intertrip
- Uprate Carlow Kellis 110 circuit 2
- Maynooth 3 * 250 MVA 220/110 transformer
- Flagford 300 MVAr SVC

Some of the reinforcements also increase interconnector transfer capability.

A set of studies were performed with the reinforcements included. The transfer capability of the 2011/12 system for the 275kV interconnector development options is compared with the 2006/7 results. The results are shown in the tables below.

The performance of another 275kV interconnector development option, a third Louth Tandragee circuit, is included with the results.

The later year studies show that some transfer capabilities degrade slightly. This is because local problems are exacerbated by load growth. Later year studies, however, show that most of the benefits of an additional interconnection will be maintained.

Power Transfer to Republic of Ireland

N-1	Power to Republic of Ireland			
	Winter		Summer	
	2011/12 TLTG Limit MW	2006/7 TLTG Limit MW	2011 TLTG Limit MW	2006 TLTG Limit MW
Basecase +				
Derry to Dublin	528	501	558	480
Belfast to Dublin	639	935	636	754
Derry to Shannon	528	501	382	434
Belfast to Shannon	639	935	382	433
Louth Tandragee ckt 3 275 +				
Derry to Dublin	387[11]	453[12]	550	489
Belfast to Dublin	979	1100	900	925
Derry to Shannon	387	453	184	387
Belfast to Shannon	566	718	184	662
Arva Tyrone 275 +				
Derry to Dublin	533	508	558	481
Belfast to Dublin	1008	1164	972	1018
Derry to Shannon	533	510	437	479
Belfast to Shannon	700	1010	435	550
Coolkeeragh Srananagh 275 +				
Derry to Dublin	685	636	695	682
Belfast to Dublin	895	1204	894	1034
Derry to Shannon	707	658	514	646
Belfast to Shannon	949	979	494	648

[11] Loss of Coolkeeragh Strabane circuit 1 overloads circuit 2
[12] Loss of Coolkeeragh Strabane circuit 1 overloads circuit 2

N-DC	Power to Republic of Ireland			
	Winter		Summer	
	2011/12 TLTG Limit MW	2006/7 TLTG Limit MW	2011 TLTG Limit MW	2006 TLTG Limit MW
Basecase +				
Derry to Dublin	204	175	148	76
Belfast to Dublin	247	247	150	150
Derry to Shannon	204	175	148	76
Belfast to Shannon	247	247	150	150
Louth Tandragee ckt 3 275 +				
Derry to Dublin	195	169[13]	144	69
Belfast to Dublin	435	544	473	757
Derry to Shannon	195	169	144	54
Belfast to Shannon	435	544[14]	473	757
Arva Tyrone 275 +				
Derry to Dublin	202	174	147	112
Belfast to Dublin	524	1030	544	770
Derry to Shannon	202	174	147	75
Belfast to Shannon	526	1019	546	772
Coolkeeragh Srananagh 275 +				
Derry to Dublin	528	484	463	364
Belfast to Dublin	535	788	557	682
Derry to Shannon	561	514	494	338
Belfast to Shannon	538	835	560	725

[13] Overload Coolkeeragh Strabane 110 for loss of Coolkeeragh Magherafelt 275 DC
[14] Overload Dungannon Tyrone 110 166 MVA for loss of Tandragee – Tyrone (Magherafelt) 275 DC

Power Transfer to Northern Ireland

N-1	Power to Northern Ireland			
	Winter		Summer	
	2011/12 TLTG Limit MW	2006/7 TLTG Limit MW	2011 TLTG Limit MW	2006 TLTG Limit MW
Basecase +				
Dublin to Derry	434[15]	737[16]	166	580[17]
Dublin to Belfast	669	737	444	580
Shannon to Derry	Nil[18]	288	166	312
Cashla to Belfast	436	638	474	551
Louth Tandragee ckt 3 275 +				
Dublin to Derry	382	334[19] 558[20]	118	598
Dublin to Belfast	671	767	438	598
Shannon to Derry	Nil	255[21]	118	296
Cashla to Belfast	466	737	496	698
Arva Tyrone 275 +				
Dublin to Derry	448	798[22]	165	617[23]
Dublin to Belfast	688	797	454	616
Shannon to Derry	nil	248	166	293
Cashla to Belfast	408	693	479	500
Coolkeeragh Srananagh 275+				
Dublin to Derry	572	509	252	624
Dublin to Belfast	683	797	234	613
Shannon to Derry	Nil	239	239	295
Cashla to Belfast	448	317	601	506

[15] Loss of Tyrone IBT1 overloads Drumnakelly Tandragee 67 MVA
[16] Includes an additional Louth Corduff 220kV circuit
[17] Includes an additional Louth Corduff 220kV circuit
[18] 110kV network between Tarbert and Cashla
[19] Loss of Coolkeeragh IBT1 overloads IBT2
[20] Loss of Tyrone IBT1 overloads Drumnakelly Tandragee 67 MVA
[21] Loss of Drumnakelly Tandragee circuit 1 overloads circuit 2
[22] Includes an additional Louth Corduff 220kV circuit
[23] Includes an additional Louth Corduff 220kV circuit

N-DC	Power to Northern Ireland			
	Winter		Summer	
	2011/12 TLTG Limit MW	2006/7 TLTG Limit MW	2011 TLTG Limit MW	2006 TLTG Limit MW
Basecase +				
Dublin to Derry	172[24] 234[25]	167 283	151	135
Dublin to Belfast	171	167	150	135
Shannon to Derry	171	172	155	139
Cashla to Belfast	179	175	157	141
Louth Tandragee circuit 3 275 +				
Dublin to Derry	220	271[26]	255	346
Dublin to Belfast	940	938	938	939
Shannon to Derry	220	271	255	346
Cashla to Belfast	940	938	938	939
Arva Tyrone 275 +				
Dublin to Derry	234	236	269	568
Dublin to Belfast	710	720	517	564
Shannon to Derry	234	236	269	293
Cashla to Belfast	845[27]	691	832	602
Coolkeeragh Srananagh 275 +				
Dublin to Derry	349	367	292	289
Dublin to Belfast	332	354	278	275
Shannon to Derry	394	393	330	327
Cashla to Belfast	398[28]	425	334	330

[24] Overload Arva Gortawee 110 for loss of Louth Tandragee 275 DC
[25] Overload Coleraine Kells 110 for loss of Coolkeeragh Magherafelt 275 DC
[26] Overload Coleraine Kells 110 for loss of Coolkeeragh Magherafelt 275 DC
[27] Overload Cashla Flagford 220 for loss of Louth Tandragee 275 DC
[28] Overload Arva Gortawee 110 for loss of Louth Tandragee 275 DC

4.6 Description of Transfer Restrictions

In the light of an expected generation deficit on the Republic of Ireland system, it is likely that the dominant medium term power transfer will be from Northern Ireland to Republic of Ireland.

Aside from some concerns about voltage step, voltage support and a need to maintain a minimum generation at Coolkeeragh, the Northern Ireland transmission system is capable of handling large power transfers to and from the border.

The Republic of Ireland system is capable of importing significant quantities of power.

The Republic of Ireland system has always been capable of importing power from Northern Ireland where that import power tended to reduce power flows on the Republic of Ireland system. For example, the Dublin to Louth corridor is heavily loaded on the Republic of Ireland system with power flowing north out of Dublin. Power imported from Northern Ireland which is facilitated by reducing generation in Dublin would reduce the existing power flow and consequently relative large import powers can be handled in this direction.

But some power imports from Northern Ireland can also tend to increase power flows on already heavily loaded routes. This happens, for example in the case of circuits from east to the west with power flowing west out of Dublin. Thus replacing power in Tarbert with power from Northern Ireland can add to the existing power flows from east to west. Consequently, it has been the case in the past that only relatively small import powers can be handled in this direction.

A number of recent and proposed reinforcements will improve the ability of the Republic of Ireland system to import power from Northern Ireland. Reinforcements that strengthen the east to west power routes include the Cashla Oldstreet 220kV line, uprating the Arva Shankill 110kV line and uprating the Louth Shankill 110kV line. Reinforcements that strengthen the Louth to Dublin power route in the southerly direction include Gorman 220kV station and a proposed Gorman - Meath Hill 110kV circuit.

Furthermore, a reactive support programme including significant capacitive support in the extreme south of the country has lessened the requirement for generation in the south operating mainly for voltage support.

Conversely, the current Republic of Ireland system is quite restricted in the amount of power that it can transport to the border for export to Northern Ireland. Even with an intact network, the circuits from Dublin to Louth are quite heavily loaded and with the network as studied there is little scope for exporting additional power to Northern Ireland.

There is, as yet, no approved project that will improve the ability of the Republic of Ireland system to export power to Northern Ireland. Regardless of whether this power would be provided for Northern Ireland from Dublin, Cork or Limerick, most of it would travel on the congested Dublin Louth corridor. In order to be capable of transporting additional power from Dublin to Louth, a significant reinforcement such as a 220kV circuit from Dublin to Louth would be required. A sensible but not necessarily optimal project, Corduff Louth 220, is included in our studies.

4.6.1 Power out of Belfast

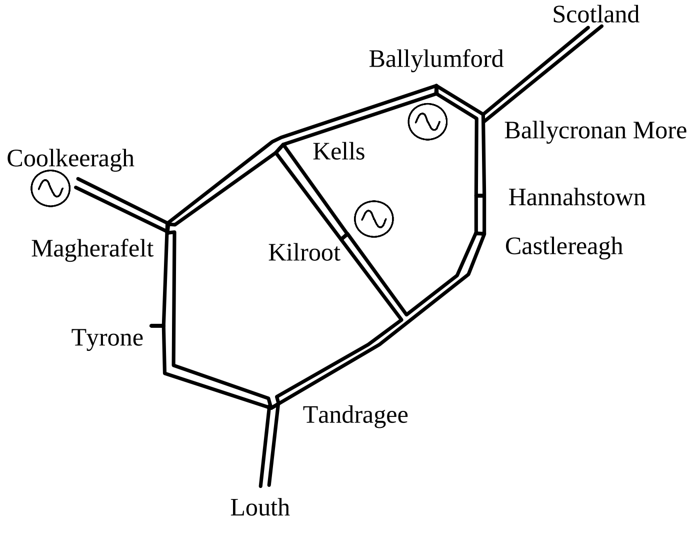
There is a large quantity of generation in the Belfast area. In particular, the combined Ballylumford generation and the DC link from Scotland, which feed into adjacent 275kV stations, represent a very large portion of the generation capacity on the island of Ireland.

It is interesting that Kilroot, although geographically close to Belfast, is electrically located near to the centre of the Northern Ireland transmission system. Thus, power transfers between Republic of Ireland and Northern Ireland that involve generation increases or reductions at Kilroot are affected by different contingencies and / or transmission constraints than that would be the case for Ballylumford or the DC link with Scotland. In particular, displacing a Kilroot generator has serious reactive power and voltage consequences for Northern Ireland.

There are proposals for additional thermal generation, both in the Republic of Ireland and in Northern Ireland. Until this generation can be commissioned, it is likely that the dominant power transfer will be from Belfast to the Republic of Ireland for the next few years.

Northern Ireland Transmission System

The Northern Ireland 275kV network is a figure of eight comprising two 275kV double circuit rings, sharing a common portion involving Kells and Kilroot. Since there have been incidences of 275kV double circuits tripping as a single contingency, the double circuit contingencies must be considered. Double circuit trips have resulted from galloping conductors, protection maloperation, lightning and terrorism.



The 275kV double circuits have high power carrying capability and, compared to the Republic of Ireland 220kV network, relatively small impedances. Traditionally, the loss of any double circuit on the main figure of eight has not caused many problems on the Northern Ireland network. The low impedance and high capacity of the 275kV circuits mean that the Northern Ireland transmission system is well capable of supplying power around the 275kV grid in either direction. However, the combined effects of generation concentration and load growth are starting to stress the system.

In a later section, it will be shown that for very high power transfers the system capacity is no longer available; for power to Republic of Ireland in which case the Northern Ireland circuits would be very highly loaded; or for power to Northern Ireland in which case the Northern Ireland generation supporting the Belfast load would be significantly reduced. In both cases, reactive power deficit is a significant issue.

Two radial 275kV double circuits are connected into this 275kV grid; the first a 275kV double circuit to Coolkeeragh in the north west and the second the Louth Tandragee 275kV double circuit interconnector to Republic of Ireland 220kV transmission system in the south. The loss of the Louth Tandragee 275kV double circuit is discussed in the previous chapter. The loss of the Coolkeeragh Magherafelt 275kV double circuit is discussed in the following pages. In essence, under low generation conditions at Coolkeeragh, the loss of the 275kV double circuit route could require load shed to prevent voltage collapse. Under high generation conditions and low load the loss of the 275kV route could overload underlying 110kV routes.

A two pole DC link from Scotland also feeds into the 275kV grid at Ballycronan More in the north east. The loss of the DC link to Scotland is approximately equivalent to the loss of the largest generator on the combined system and is not a problem for the Irish transmission system. Any 275kV fault on the network in Northern Ireland causes the link converter to block momentarily depriving the system of the generation from Scotland. Unblocking should be fast enough to prevent frequency transients. Voltage transients need to be studied in fast timeframes.

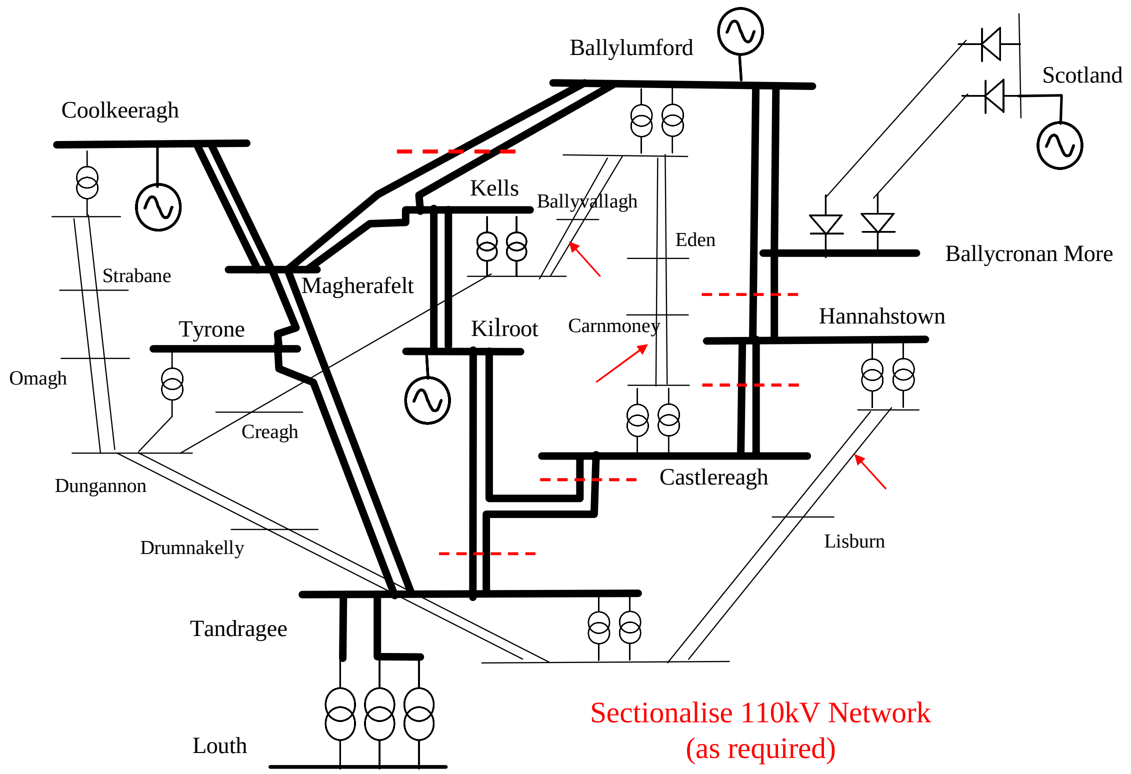
Swing Bus

Care needs to be taken when modelling the Northern Ireland system with respect to the use of the system swing bus. The swing bus, by definition, will produce infinite MVAr to achieve its target voltage. Because the Northern Ireland 275kV transmission system is relatively compact and the paths have a low impedance, any over-estimation of the strength of one node will overstate the strength of the Northern Ireland system. Thus, locating the swing bus on the Northern Ireland transmission system might mask voltage problems on the Northern Ireland transmission system.

For the purpose of the joint studies, it has been considered sufficient to occasionally compare the results with a case with the swing bus located in Aghada.

Northern Ireland approach to 110kV Network Sectionalising

A number of 275kV double circuits on the Northern Ireland system are in parallel with 110kV circuits as shown in the figure below. Under certain conditions, the Northern Ireland network can reach a stage where the loss of certain 275kV double circuits will overload the underlying 110kV circuits. The 275kV double circuits in question are shown by the dotted lines in the figure below. The solution in these cases is to sectionalise the underlying 110kV network as the need arises. This eliminates the risk of the overload occurring. The expectation is that the Northern Ireland 275kV ring is sufficiently strong that the sectionalising of the 110kV network does not affect system strength. This may not continue to be the case at very large power transfers.



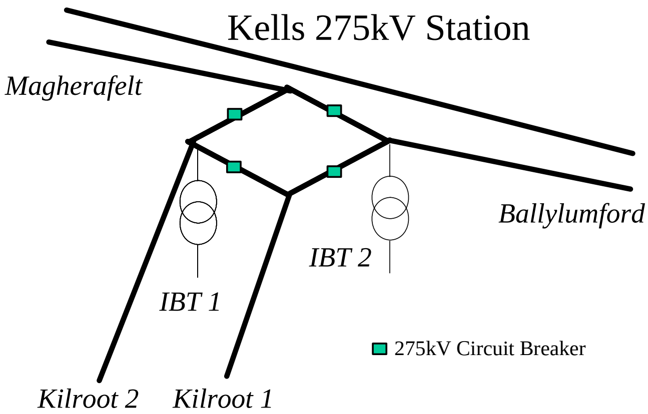
The conditions that trigger the need to sectionalise the 110kV networks are whenever there is a power transfer towards Republic of Ireland and whenever there is a large quantity of power coming from the Ballylumford / Ballycronan More area. These conditions tend to occur during power transfer to Republic of Ireland.

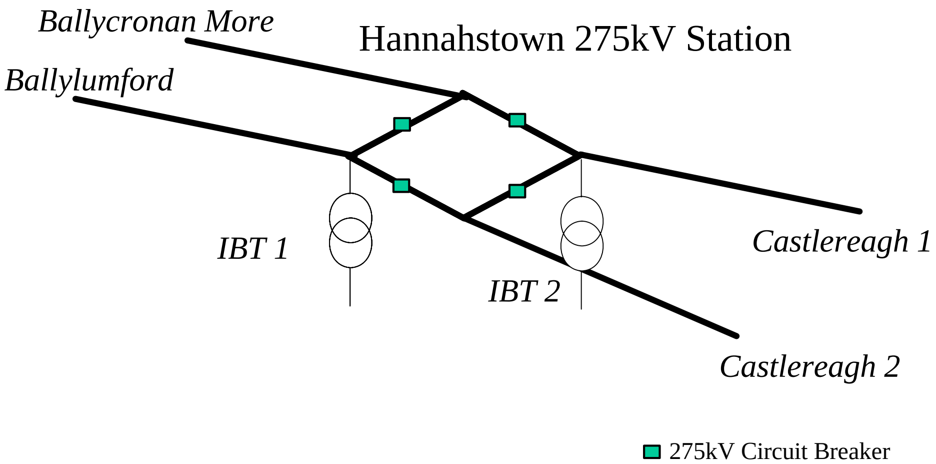
The three 110kV networks that are sectionalised are shown by arrows in the figure above. The most severe 275kV double circuit contingency in each case is as follows.

- Open 110kV network between Castlereagh and Carnmoney to cater for the loss of the Hannahstown to Ballycronan More / Ballylumford 275kV double circuit.
- Open 110kV network between Hannahstown and Lisburn to cater for the loss of the Tandragee to Castlereagh / Kilroot 275kV double circuit
- Open 110kV network between Kells and Ballyvallagh to cater for the loss of the Ballylumford to Kells / Magherafelt 275kV double circuit.

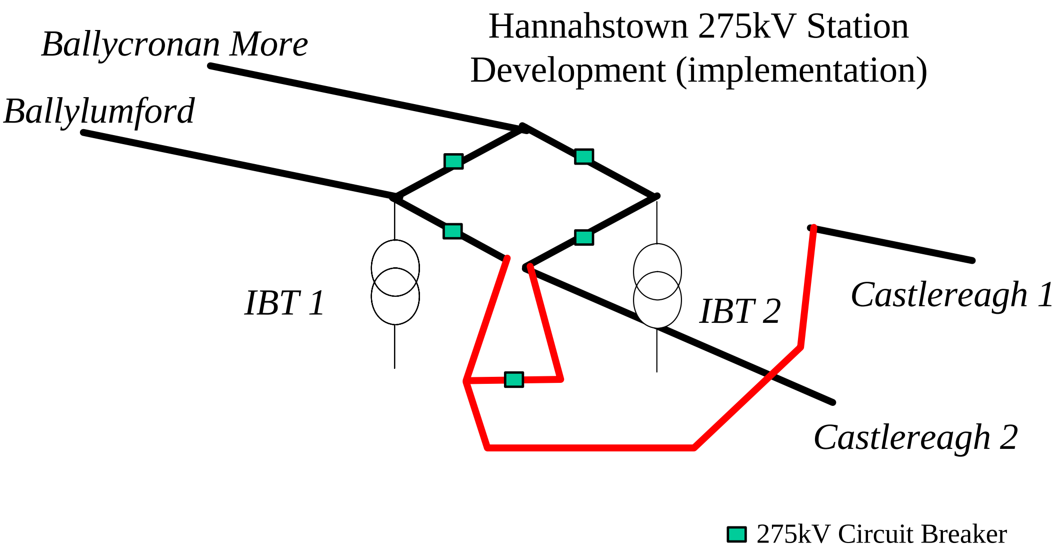
275kV Mesh Arrangement at Kells

The 275kV station arrangement in both Kells and Hannahstown 275kV station uses a simple mesh arrangement, as shown. This arrangement is sub-optimal in that the loss of one of the circuits also removes a 275/110kV transformer. Further, since the circuits involved are part of double circuits, a single contingency involving a double circuit tower on a circuit to the stations would therefore take two 275kV circuits and a 275/110kV transformer.

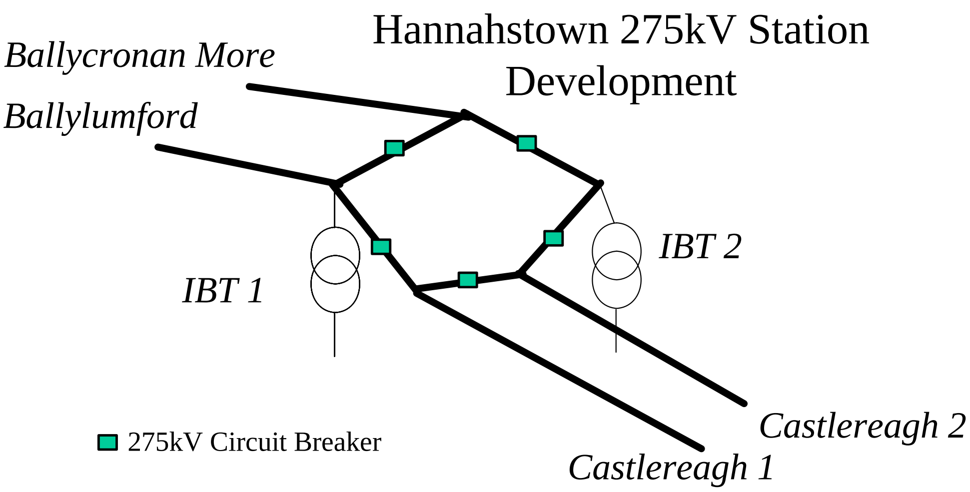




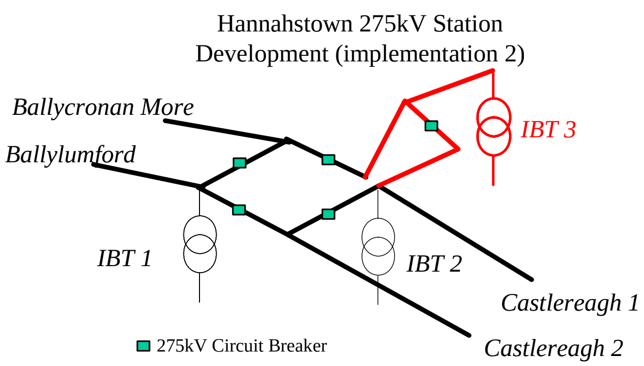
This contingency can overload the solitary remaining transformer. The problem in Hannahstown is primarily due to the large load that is fed at 110kV from the station but because the 110kV network from Hannahstown also offers a path to Republic of Ireland, the severity of the overload is related to power transfers to Republic of Ireland.



A possible development option to reconfigure the 275kV mesh is shown above. The electrical layout of this proposed change would be as shown below. With this new arrangement, the loss of the Hannahstown Castlereagh 275kV double circuit no longer also results in the loss of Hannahstown 275/110 IBT2.

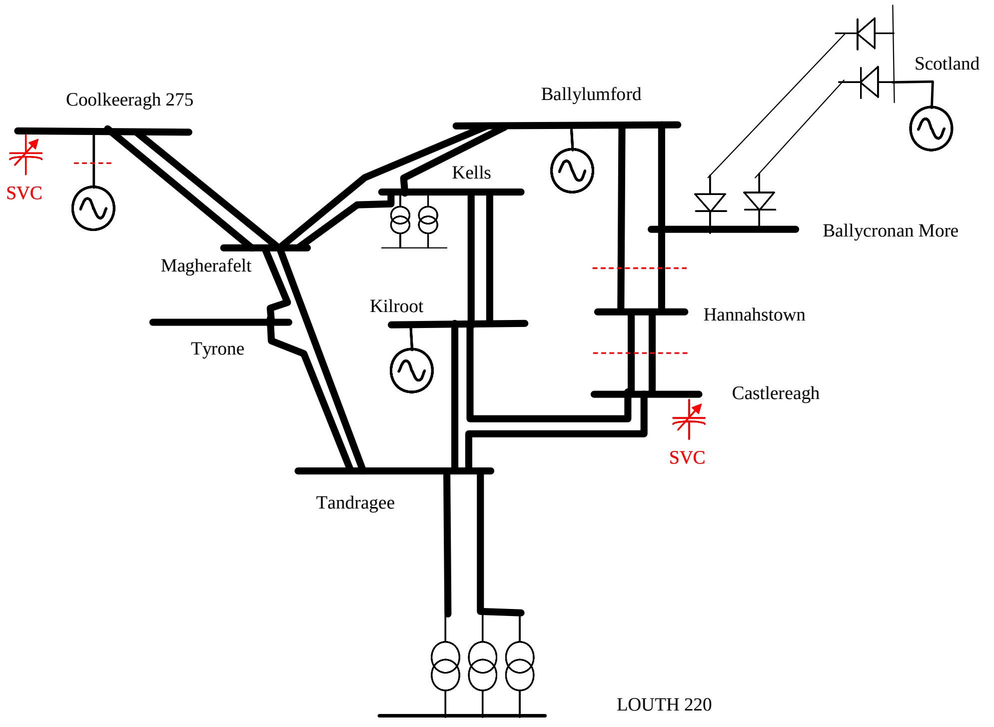


While this project does solve the triple outage from happening as a single contingency, it may have little other benefit for interconnector transfer capability. Because of the large load fed from Hannahstown, the single contingency loss of either 275/110 transformer may still overload the other. This need for additional transformer capacity could be addressed by installing larger transformers or a third 275/110 transformer for the station (alternative station reconfiguration – perhaps) or some other more strategic approach.



Then, the 110kV network may still need to be sectionalised for large trades to Republic of Ireland to prevent overloading the 110kV lines for the loss of the Hannahstown Castlereagh 275kV double circuit.

Voltage Step / Low Voltage for loss of 275kV Double Circuit



The Northern Ireland 275kV network is composed of 275kV double circuits arranged in a figure of eight. This arrangement is robust. Traditionally, the loss of any part of the ring, even a double circuit, has not caused any problems on the Northern Ireland transmission network.

However, at higher power transfers to the Republic of Ireland, this is no longer the case. At a power transfer of approx 500 MW to the Republic of Ireland, the loss of the Hannahstown Ballycronan More 275kV double circuit (and associated 275/110kV transformer) will cause a significant voltage step and low voltage on the Northern Ireland transmission network. The severity of the voltage step is dependent on generation dispatch and is more severe when generation is reduced at Kilroot. There is a significant risk of voltage collapse without the two generators at Kilroot.

During periods of low generation at Coolkeeragh, and at high power transfer, the loss of the Magherafelt Kells 275kV double circuit can also cause voltage step problems.

It is likely that dynamic reactive support, such as a large SVC will be required at Castlereagh to facilitate power transfers to the Republic of Ireland in excess of 500 MW.

In predicting the risk of voltage collapse, system operators need to be aware of the following considerations:

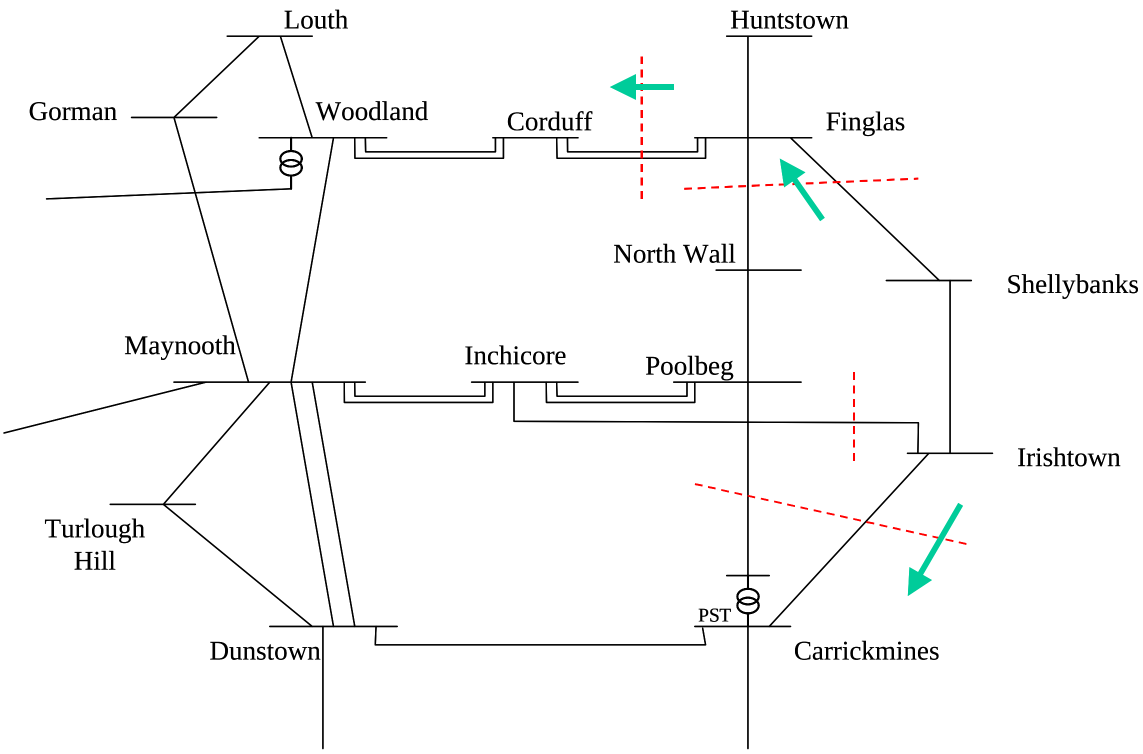
- Location and behaviour of swing bus in system model
- Sectionalising of 110kV network at high power transfers
- Due to 275kV mesh at Kells and Hannahstown, there are a number of instances where three network components can be lost in a single contingency
- whether SCADA contingency analysis software is required for the all island network

4.6.2 Power out of Dublin

Dublin is one of the most generation intensive locations in the country. During overlapping outages of Northern Ireland generation and / or reductions in the power available from Scotland, it is highly likely that Republic of Ireland may be supplying power to Northern Ireland. When that happens, most of the power will be sourced in Dublin.

Furthermore, existing infrastructure and access to experienced power station staff appears to make the Dublin area an attractive place to locate new generation. Consequently, it is important to examine the ability of Republic of Ireland transmission system to get power from Dublin to the border.

Dublin 220kV network



The studies assumed additional generation in Dublin. Under this assumption, a number of transmission bottlenecks are identifiable on the Dublin 220kV network.

Because the bottlenecks are associated with hypothetical additional generation which, in fact, does not exist, no reinforcements had been identified for this area.

Studying the Dublin 220kV network is complex. Most of the circuits are cables. Cables generally have quite high overload capabilities. But the post-fault overload capabilities depend on the pre-contingency loading of the cables.

Any likely reinforcement of the Dublin 220kV network would be generation location dependent. I.e. if generation was to retire or locate in the area, the optimum reinforcement would depend on where that generation retired or located.

In addition, the fault level in Dublin is quite high. It is likely that should any additional generation locate in Dublin, this generation will require a significant reconfiguration of the Dublin 220kV network to meet both fault level and circuit loading requirements.

For these reasons, problems on the Dublin 220kV cable network are not considered in this report.

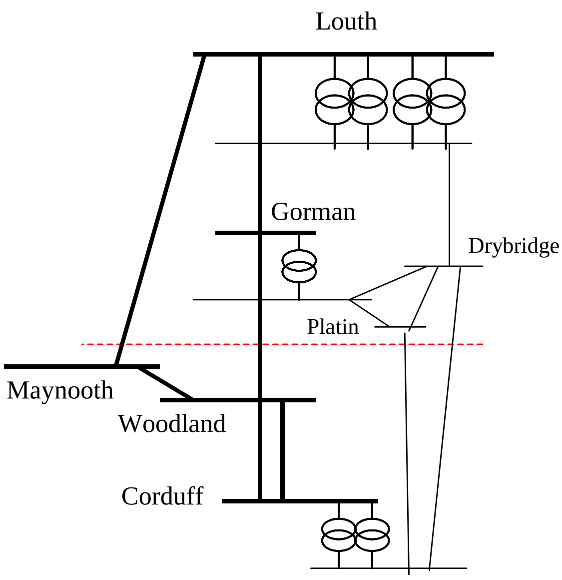
Corduff Finglas 220 ckt 3

In our studies, when transferring power from Dublin to Northern Ireland, the loss of one Corduff Finglas 220kV circuit, overloaded the other Corduff Finglas 220kV circuit.

This consideration may no longer be an issue for power transfer to Northern Ireland because the proposed additional generation at Huntstown power station is to be connected by a direct feed into Corduff, which effectively forms a parallel circuit to the existing Corduff Finglas circuits.

Corduff Louth 220

The two principal 220kV paths between Dublin and Louth, as shown below, are firstly Louth Gorman 220 and Gorman Maynooth 220kV and secondly Louth Woodland 220kV. Even without power transfers to Northern Ireland, the loss of either of the 220kV circuits is very severe for the Republic of Ireland system. The loss of either circuit can overload the underlying 110kV networks and/or the remaining 220kV route.



Consequently, for a significant part of the studies, it is assumed that a third 220kV circuit exists between Dublin and Louth; namely Corduff Louth 220. This is deemed to be a sensible but not necessarily optimal project.

220/110kV transformer capacity

In the studies, there were two 125 MVA transformers and a single 250 MVA transformer at Maynooth. Studies with additional generation in the Dublin area increase the loading on the

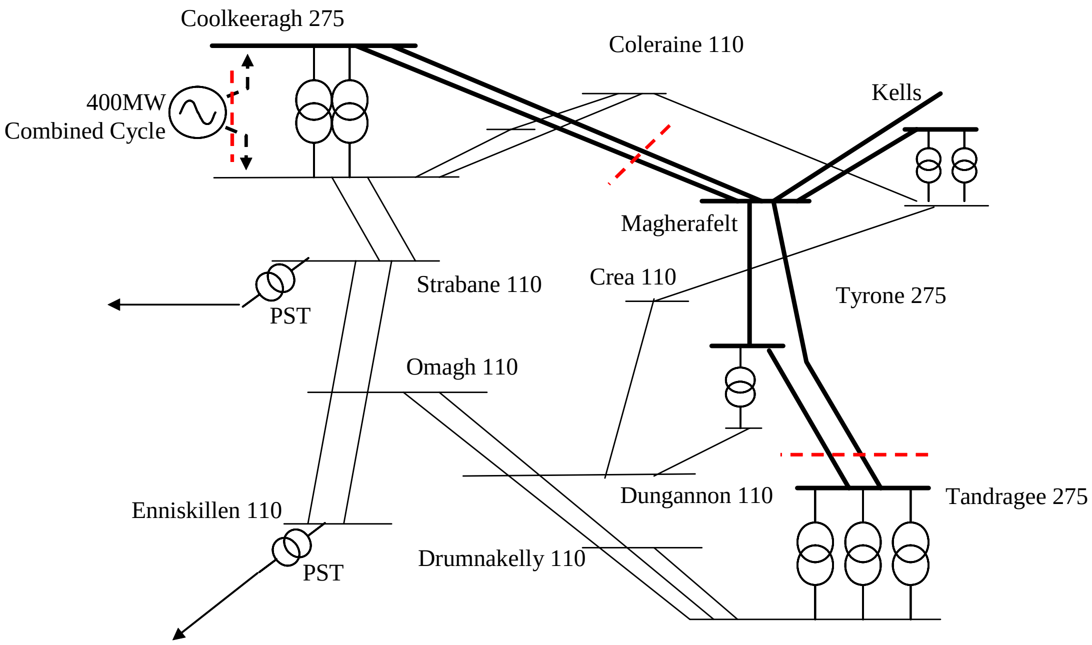
Maynooth transformers. Eventually, loss of the 250 MVA transformer overloads both the 125 MVA transformers.
For the purpose of the studies, it is necessary to replace the two 125 MVA transformers with two 250 MVA transformers at Maynooth. This results in three 250 MVA transformers at Maynooth.

Gorman Navan 110 ckt 3

The two Gorman Navan 110 circuits and Navan Arva 110 form a parallel path to part of the Dublin Louth corridor described above. In addition, the load at Navan is quite high.

Loss of either Gorman Navan 110kV circuit overloads the other circuit. A possible solution would be to construct a third Gorman Navan 110kV circuit.

4.6.3 Power to and from Derry



Coolkeeragh 275kV station is an important hub for the north west of the interconnected Republic of Ireland and Northern Ireland transmission systems.

A measure of support for the Republic of Ireland system in Donegal is provided from Coolkeeragh 275kV station as follows. The 110kV interconnector between Strabane and Letterkenny has a power flow controller (phase shift transformer) which is configured so that power does not flow along this circuit for normal operating conditions. However, for the loss of a circuit or generator on either system, some power will flow across these circuits to the weakened system.

There is a 400 MW combined cycle generator under construction at Coolkeeragh. Part of the output of this generator feeds onto the 275kV network at Coolkeeragh and part feeds onto the 110kV network – but it is a single generator. This gas powered generation at Coolkeeragh, when running, will be sufficient to meet local requirements.

Coolkeeragh SVC

Aside from supporting the local network, it is described in the last section how the 400MW generator at Coolkeeragh is vital to supporting the entire transmission system for very large power transfers between Belfast and Republic of Ireland. It is possible that a large Coolkeeragh SVC may be required to cater for the loss of the Coolkeeragh 400 MW generator during large cross border trades.

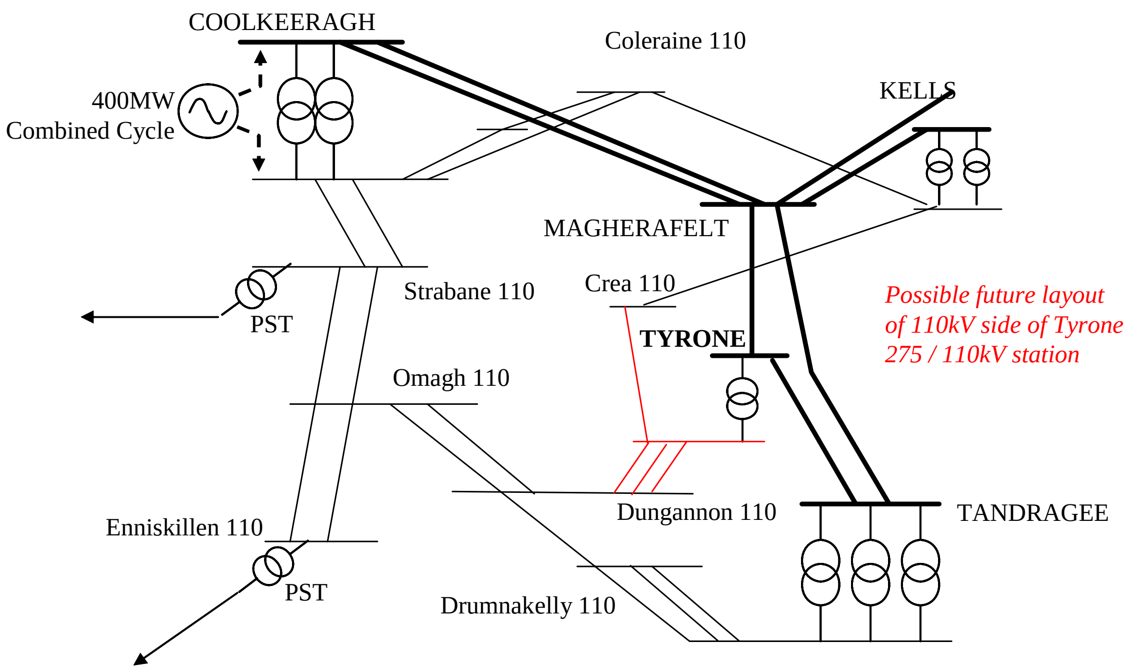
Requirement for Coolkeeragh Generation

The Coolkeeragh Magherafelt 275kV double circuit connects the station to the Northern Ireland 275kV grid. Most of the power imports and exports with the area will flow on this 275kV double circuit. In the absence of the Coolkeeragh 400 MW generator; the Coolkeeragh Magherafelt 275kV double circuit is capable of supplying the power needs of the area, even withstanding a single N-1 contingency.

There is a special protection scheme which sheds load in the Derry area in the unlikely event that a loss of the Coolkeeragh Magherafelt 275kV double circuit occurs at the same time as the Coolkeeragh generation is off load.

Tyrone 110kV Development

The Northern Ireland 110kV transmission network in the west is arranged in a ring. This ring is currently fed from Coolkeeragh 275kV station in the north west, Tandragee 275kV station in the south and Kells 275kV station in the north east. A new 275kV transmission station is currently being proposed at Tyrone.



The first phase of the Tyrone 275kV project will have a single 110kV transformer feeder injecting into the 110kV network at Dungannon. The 275/110kV transformer is expected to have a 120 MVA rating[29] and the 110kV line shall have a 166 / 144 MVA rating. Under certain transfer conditions, the loss of either Tandragee – Magherafelt / Tyrone 275kV double circuit or Coolkeeragh / Magherafelt 275kV double circuit can overload the Tyrone 275/110 120MVA transformer. The overloads occur for power transfers to Republic of Ireland and for power transfers to Derry respectively. The overloads would be solved by replacing the proposed 120 MVA transformer with a Tyrone 275/110 240 MVA transformer or by placing a 240 MVA transformer in parallel with the 120 MVA transformer. Even if the 120 MVA transformer is replaced with a 240 MVA transformer, the 166 / 144 MVA line soon begins to overload. Therefore, as soon as the Tyrone transformer uprating is required, it is likely that the Tyrone 110kV station will be completed as shown.

If the Arva Tyrone 275kV interconnector development option is constructed, it will provide a parallel path south of Tyrone to Republic of Ireland. This reinforcement, therefore, will solve the problems caused for the loss of the Tandragee – Magherafelt / Tyrone 275kV double circuit. Arva Tyrone 275kV will not solve the problems associated with the loss of the Coolkeeragh Magherafelt 275kV double circuit.

Remedial Action Scheme – Coolkeeragh run back

There is a possibility of large quantities of wind power being generated in the north west of the network. It is the export of this additional wind power which is likely to test the transmission system in this area. For large power transfers out of Derry, the loss of the Coolkeeragh Magherafelt 275kV double circuit can overload 110kV networks in the area.

In order to facilitate wind generation locating in this area, NIE are installing a remedial action scheme which, if there is the risk of overloading the 110kV circuits out of Coolkeeragh, will send a run back signal to the Coolkeeragh 400 MW unit on the loss of the Coolkeeragh Magherafelt 275kV double circuit. The signal will immediately trip the steam turbine and then reduce the output of the gas turbine to about 170 MW over two minutes.

Donegal 110kV reinforcement & Coleraine Kells 110 circuit 2

A sensitivity analysis is performed on the impact of two potential 110kV reinforcements in the border area: Coleraine Kells 110kV circuit 2 and Donegal 110kV reinforcement. Both of the reinforcements are useful for local transmission reasons, but they make little or no difference to total transfer capability.

In the example of the Donegal 110kV reinforcement, the loss of Louth Tandragee 275kV double circuit would still

- overload Strabane Letterkenny 110 and Corraclassy Enniskillen 110kV,
- cause voltage collapse difficulties if the power is heading north and
- cause transient stability problems.

[29] Since these studies were performed, Northern Ireland Electricity has begun to consider installing a 240 MVA transformer at Drumkee in place of the 120 MVA that was originally proposed and possible reorganisation of the local 110kV lines. The implications of this are addressed in the next report.

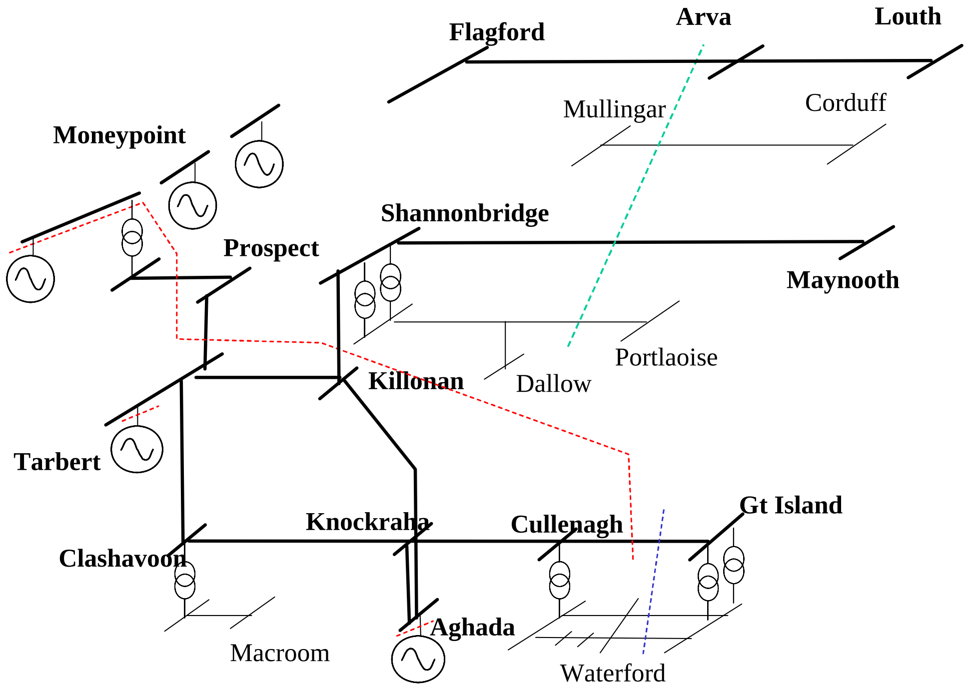
4.6.4 Power to and from Tarbert

Trading power from Northern Ireland to the south west of the Republic of Ireland system involves reducing generation in the south west and increasing generation on the Northern Ireland transmission system. Power then flows from Northern Ireland to the south west.

Because of the relative prices of some of the generation in the south, this power transfer seems very attractive and would be of benefit to consumers. It is unfortunate therefore that, with the system as studied, large power transfer could risk thermal overloads and voltage collapse problems on the Republic of Ireland system.

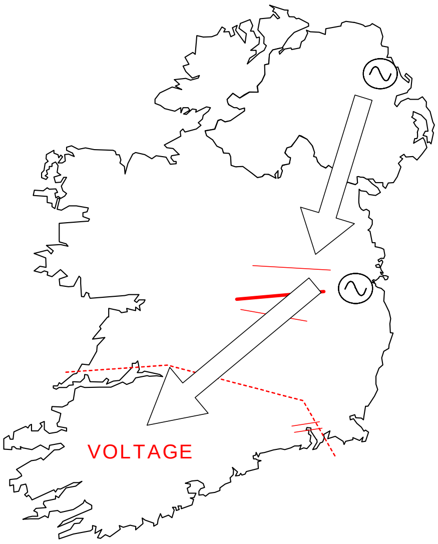
Overloads on East West Circuits

This power transfer increases the loading on some already highly loaded circuits that run from east to west on the Republic of Ireland system. At a given power transfer to Tarbert, the loss of one of the circuits would cause an unacceptable overload on another. The circuits involved are Flagford Louth 220, Corduff Mullingar 110, Shannonbridge Maynooth 220, Portlaoise Dallow Shannonbridge 110, Cullenagh Great Island 220 and Great Island Waterford 110 circuits 1 and 2. The circuits are shown below as the circuits crossing the green and blue lines respectively.

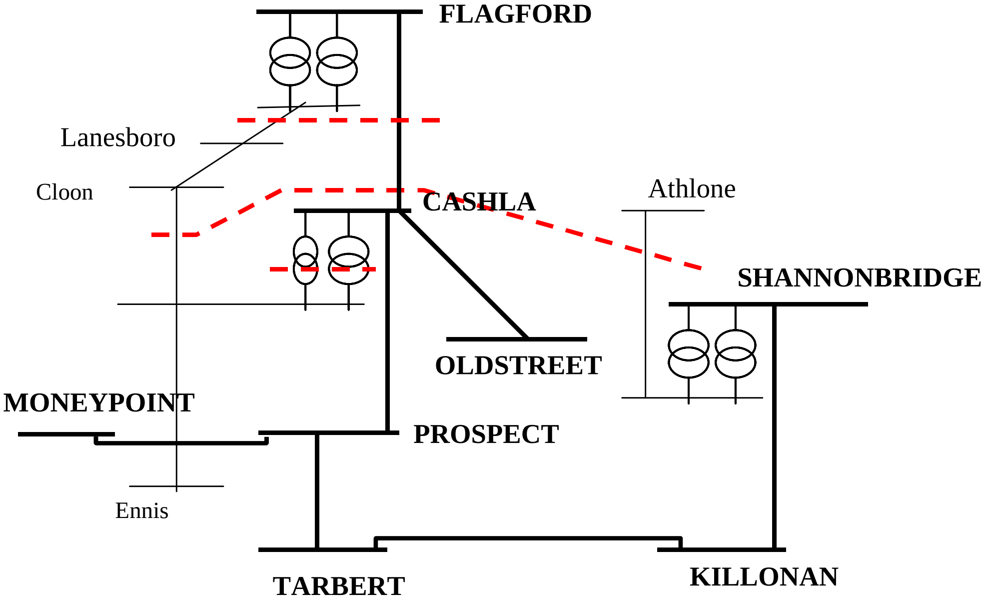


Separate from the thermal overload problems associated with transferring the power to the south, the generation in the south also performs a vital function in supporting the voltage in the south. Reducing generation in the south west to facilitate a trade from Northern Ireland removes a lot of this voltage support. At a given transfer to Tarbert, the loss on contingency of another large generator or of one of the key 220kV circuits into the south will result in voltage collapse. The contingencies are represented as crossing the red dotted lines in the network diagram, above.

A geographical representation of the thermal overload and voltage collapse issues is shown below.



Overloads on North South Circuits



Overload on Cashla Cloon 110

For power transfer to Northern Ireland from the south west, the loss of Flagford Cashla 220 overloads Cashla Cloon 110. This line is already rated at 126 / 107 MVA so any uprating would require new conductors.

Overload on Cashla Ennis 110

For power transfer to Northern Ireland from the south west, the loss of Prospect Tarbert 220 could result in overloads on Cashla Ennis 110.

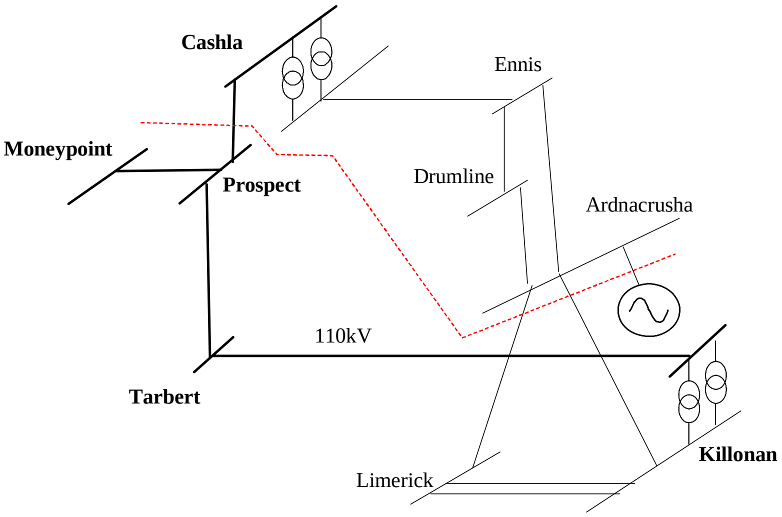
Overload on Athlone Shannonbridge 110

In the other direction, for large power transfers from the south west to Northern Ireland, loss of Cashla Flagford 220 results in an overload on the Athlone Shannonbridge 110.

Overloads in the Ardnacrusha area

A number of maintenance and trip combinations in the Ardnacrusha Limerick area cause overloads in the 2006 summer studies. While it is unlikely that a maintenance outage on the circuits would be performed in the absence of Ardnacrusha generation, it is reasonable to assume that outages of Ardnacrusha generation might be allowed with an intact transmission network. The Ardnacrusha generator outages would relate to the availability of water and to the need to perform essential generator maintenance.

Maintenance and trip combinations of the 110kV circuits and Ardnacrusha generation appear to be independent of power transfer with Northern Ireland. However, maintenance and trip combinations which involve Cashla Prospect 220 are influenced by the power transfer with Northern Ireland.



A second Ardnacrusha Killonan 110kV circuit is included in the case for the transfer of 600 MW to Tarbert and it appeared to solve the Ardnacrusha area problems.

The use of the hydro generation as an energy reserve for some of the larger infeeds on the Irish system and given that the hydro stations are relatively small means that the running regime for the hydro stations has changed in the past few years. It is conceivable that following the loss of a generator or infeed for fault or economic reasons, it may be necessary to run Ardnacrusha flat out for relatively long period of time to meet the energy shortfall. For example, the DC infeed from Scotland may reduce from 400 MW to zero at short notice depending on the price of electricity in the U.K. Thereafter, Ardnacrusha would receive relatively little running until the water level in the region has recovered. The point is that Ardnacrusha may be a less reliable generation source than before and it may be necessary to consider reinforcing the area with Ardnacrusha Killonan 2.

Overload on Arva Shankill 110

Arva Shankill 110kV circuit is an existing line with steel tower construction. A recent uprating on this circuit only uprated the circuit from 72 MVA to 86 MVA summer rating. This uprating is adequate for the internal needs of the Republic of Ireland transmission system, not considering the requirements to import power from Northern Ireland. It may now be appropriate to uprate this circuit to 107 MVA summer rating to increase import capability from Tarbert.

An advantage of the Arva Tyrone 275kV project is that it provides a parallel path to Arva Shankill 110 and alleviates the loadings on this circuit that would occur for the loss of Flagford Louth 220. Arva Tyrone will not alleviate the overload of Arva Shankill 110 for the loss of Louth Lisdrum 110 and Louth Shankill 110. That is a local issue.

Since these studies were performed, ESB National Grid has begun to consider a reinforcement in this area.

220/110kV transformer capacity

Studies with additional generation in the south west resulted in overloads on the Cashla transformers, the Killonan transformers and the Tarbert transformers. Some of the studies also resulted in voltage problems and overloads on the underlying 110kV network.

It is important to note that the additional generation is presumed to connect to the 220kV network in the area.

Both Arva Tyrone and Coolkeeragh Srananagh 275kV interconnector development options strengthen the Republic of Ireland 220kV network in the north of the system. Consequently, Cashla 220kV bus is a stronger point with the reinforcements. Therefore, more power flows down through the Cashla transformers in the base case when either 275kV interconnector development option is studied.

The arrangement as studied in Cashla is a 250 MVA 220/110 transformer in parallel with a 175 MVA transformer. The 175 MVA transformer is actually an uprated 125 MVA transformer and, as such, has no overload capability. The transformers are highly loaded in the base case. For power transfers to Northern Ireland from the south west, the loss of the 250 MVA transformer overloads the 175 MVA transformer. Replacing the 175 MVA transformer with a 250 MVA transformer would solve this problem.

Since these studies were performed, ESB National Grid has begun to consider additional transformer capacity at Cashla.

The present arrangement in Killonan is a 125 MVA transformer in parallel with two 63 MVA transformers. For the purpose of the studies, it is necessary to replace these in the model with three 125 MVA transformers.

5 Maintenance

The previous section is concerned with the performance of the intact transmission network. In both Northern Ireland and the Republic of Ireland it is not unusual for some circuits to be temporarily removed from service. The outages are required to facilitate essential maintenance or to allow for equipment upgrades or for new connections to the transmission system. Most of the outages are scheduled to occur during the summer months when the demand for electricity is significantly lower than during the winter months.

The present trading practice is that interconnector capacity is auctioned for one, two or three years but the Transmission System Operators reduce the capacity in, or close to, real time if important circuits are out of service.

An investigation is performed to examine the impact of the maintenance outages on the available transfer capacity. The 2006 summer case is tested to determine the relationship between power transfer capability and maintaining an adequate transmission system. In maintenance conditions, this means that the system shall be capable of withstanding the loss due to fault of any item of plant on the system even during the outage for maintenance of any other item of plant. This maintenance and trip outage combination is often referred to as an N-1-1 (or as n-m-t).

Assumptions

It is assumed that Republic of Ireland and Northern Ireland can co-ordinate transmission maintenance requirements. I.e. it is assumed that the simultaneous outage for maintenance of two interacting items of transmission plant can be avoided.

A number of additional reinforcements are added to the study case.

- Killonan three 125MVA transformers
- Uprate Killonan Limerick 110 ckt 2 – 107MVA (per ckt 1)
- Uprate Carlow Kellis 110 ckt 2 – 107MVA (per ckt 1)

Treatment of the Loss of a Double Circuit

The studies do not cover the loss due to fault of a double circuit tower during the outage for maintenance of any item of plant. This combination would be referred to as N-1-DC and is not required in the Northern Ireland transmission planning criteria or in the Republic of Ireland transmission planning criteria.

			Power to Northern Ireland				Power to Republic of Ireland				
outage 1	**outage 2**	**overload**	300 to Belfast Cor Lou 220 Cor Fin 3 220	**300 to Belfast**	**150 to Belfast**	**no transfer**	**300 to Tarbert**	**600 to Tarbert**	600 to Tarbert Mpt Tarb 220 ard kill 110	**600 to Dublin**	900 to Dublin Arv Tyr 275 Gor MeHil 110
Hannahstown IBT1	Hannahstown IBT2	Lisburn Tandragee 110	1%	1%	1%						
Hannahstown Castlereagh 275 ckt 2	Hannahstown Castlereagh 275 ckt 1 with IBT1	Hannahstown IBT2								-	7%
Ballylumford Hannahstown 275	Ballylumford Moyle 275									VC	**NC**
Louth Tandragee 275 ckt 2	Louth 300 MVA AT1	Louth 300 MVA AT2		-				79%	78%	78%	
Louth Tandragee 275 ckt 2	Irishtown 400MW (or other ESB	Louth 300 MVA AT1 and AT2		-					4%	9%	
Louth Tandragee 275 ckt 1	Louth Tandragee 275 ckt 2		**VC**	**VC**	-	**-**	0.92pu	**VC**	**VC**	**VC**	
Corduff Louth 220	Louth Woodland 220	Gorman Maynooth 220	1%	1%							
Corduff Louth 220	Gorman Maynooth 220	Louth Woodland 220	2%	2%							
Louth Woodland 220	Gorman Maynooth 220	Corduff Louth 220	1%								
Louth Woodland 220	**Gorman Maynooth 220**	Corduff Platin 110		164% .. 0.82pu	91%	40%					
Louth Woodland 220	**Gorman Maynooth 220**	Drybridge Louth 110									1%
Louth Woodland 220	Gorman Louth 220	Drybridge Louth 110		121% .. 0.9pu	49%						49%
Louth Woodland 220	Coolkeeragh CC (or other NIE	Gorman Maynooth 220		38% .. 0.87pu	14%						
Louth Woodland 220	Corduff Drybridge 110	Corduff Platin 110		31%	7%						
Louth Woodland 220	**Cashla Flagford 220**	Gorman Maynooth 220		23%							
Louth Woodland 220	Gorman T2101	Corduff Platin 110		17%	1%						
Louth Woodland 220	**Cashla Oldstreet 220**	Gorman Maynooth 220		15%							
Louth Woodland 220	Cashla Prospect 220	Gorman Maynooth 220		11%							
Louth Woodland 220	Corduff T2101	Gorman Maynooth 220		8%							
Louth Woodland 220	**Athlone Shannonbridge 110**	Gorman Maynooth 220		6% .. 0.9pu							
Gorman Maynooth 220	**Corduff Drybridge 110**	Corduff Platin 110		44%	19%						
Gorman Maynooth 220	Coolkeeragh CC (or other NIE	Louth Woodland 220 and Corduff Platin 110		36% .. 0.88pu	13%						
Gorman Maynooth 220	Cashla Flagford 220	Louth Woodland 220 and Corduff Platin 110		21%							
Gorman Maynooth 220	**Corduff Finglas 220 ckt 1**	Corduff Finglas 110 ckt 2		20%							
Gorman Maynooth 220	**Cashla Oldstreet 220**	Corduff Platin 110 or Louth Woodland 220		15%							
Gorman Maynooth 220	Cashla Prospect 220	Louth Woodland 220 and Corduff Platin 110		10%							
Gorman Maynooth 220	Corduff T2101	Louth Woodland 220 and Corduff T2102		10%							
Gorman Maynooth 220	Corduff Mullingar 110	Corduff Platin 110		7%							
Gorman Maynooth 220	Gorman Louth 220	Louth Woodland 220		7%							
Gorman Maynooth 220	Gorman T2101	Louth Woodland 220		7%							
Gorman Maynooth 220	Athlone Shannonbridge 110	Louth Woodland 220		6%							
Gorman Maynooth 220	Louth T2104	Louth Woodland 220		5%							
Gorman Louth 220	Coolkeeragh CC (or other NIE	Louth Woodland 220		21% .. 0.9pu							
Gorman Louth 220	Gorman T2101	Louth Woodland 220		7%							
Gorman Louth 220	Cashla Flagford 220	Louth Woodland 220		5%							
Gorman Louth 220	Gorman Navan 110 ckt 1	Gorman Navan 110 ckt 2		7%							
Gorman Louth 220	Arva Flagford 220	Drybridge Louth 110									6%
Gorman T2101	Corduff Drybridge 110	Corduff Platin 110		25%	13%	1%					
Gorman T2101	**Corduff Platin 110**	Corduff Drybridge 110		14%	2%						
Gorman T2101	Louth - Meath Hill 110	Drybridge Louth 110									8%
Cashla Flagford 220	Dalton Galway 110	Cashla Cloon 110		7%	3%						
Cashla Flagford 220	Cashla Cloon 110	Dalton Galway 110		5%							
Corduff Finglas 220 ckt 1	Coolkeeragh CC (or other NIE	Corduff Finglas 220 ckt 2		10%							
Corduff Finglas 220 ckt 1	Moneypoint G1	Corduff Finglas 220 ckt 2		6%							
Corduff Finglas 220 ckt 1	Cashla Prospect 220	Corduff Finglas 220 ckt 2		4%							
Cashla Prospect 220	Corduff Mullingar 110	Athlone Shannonbridge 110		1%							
Cashla Prospect 220	Ballylumford CC (or other NIE g	Athlone Shannonbridge 110		3%							
Corduff T2101	Corduff T2102	Maynooth Ryebrook 110	53%	70%	60%	50%				21%	
Corduff T2101	Maynooth Ryebrook 110	Corduff T2102		8%	1%				2%		
Cashla 250 MVA T2101	Prospect Tarbert 220	Cashla 175 MVA T2102		-			20%	12%			
Cashla 175 MVA T2102	Prospect Tarbert 220	Cashla 250 MVA T2101					8%				
Cashla 250 MVA T2101	Cashla Flagford 220	Cashla 175 MVA T2102			1%						
Oldstreet Woodland 400	Prospect Tarbert 220	Cashla 250 MVA T2101									2%
Oldstreet Woodland 400	Cashla 250 MVA T2101	Cashla 175 MVA T2102									5%

% = circuit overload

p.u. = low voltage

Results

A number of maintenance and trip combinations are very sensitive to interconnector power transfer. These are detailed below. In addition to reporting the performance of the base network, a sensitivity analysis is also performed on three of the transfer scenarios to examine the impact of additional system reinforcements. The reinforcements change the pattern relating transfer capability to transmission line maintenance.

The reinforcements of interest are

- Corduff Louth 220 and Corduff Finglas 220 ckt 3 for the transfer of 300 MW to Belfast;
- Moneypoint Tarbert 220 and Ardnacrusha Killonan 110 ckt 2 for the transfer of 600 MW to Tarbert and
- Arva Tyrone 275kVand Gorman Meath Hill 110kV for the transfer of 900 MW to Dublin.

The outage for maintenance of a number of key circuits affects the available power transfer capability. Those circuits are listed below and cross referenced with the power transfer which would cause problems. From the previous information it is possible to compile a table showing the relationship between power transfer and the chance to take various transmission circuits out for maintenance.

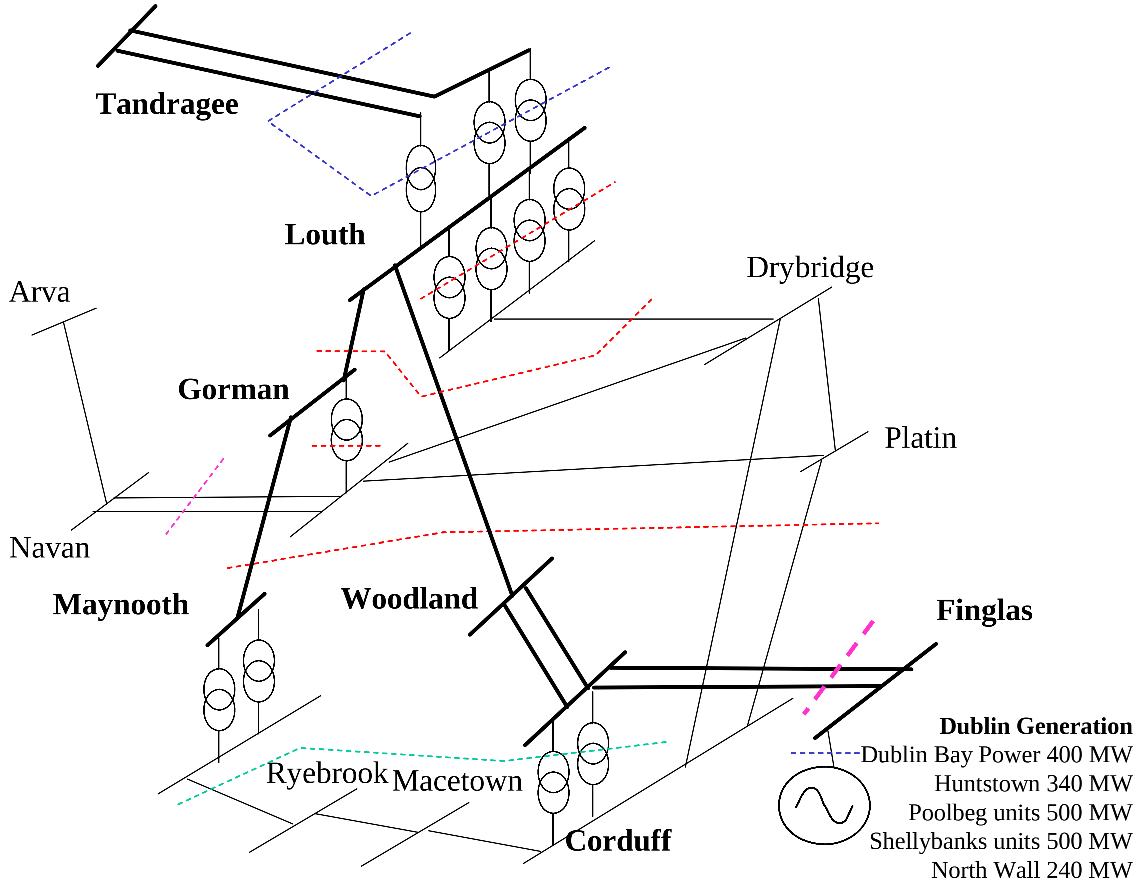
	Power to Northern Ireland				Power to Republic of Ireland				
	300 to Belfast Cor Lou 220 Cor Fin 3 220	**300 to Belfast**	**150 to Belfast**	**no transfer**	**300 to Tarbert**	**600 to Tarbert**	600 to Tarbert Mpt Tarb 220 ard kill 110	**600 to Dublin**	900 to Dublin Arv Tyr 275 Gor MeHil 110
Hannahstown IBT1	1	1	1						
Louth Tandragee 275kV ckt 1	1	1			1	1	1	1	
Louth 600 MVA AT3	1	1			1	1	1	1	
Louth 300 MVA AT1						1	1	1	
Cashla 250 MVA T2101			1		1	1			1
Corduff Louth 220	1								
Louth Woodland 220	1	1	1	1					1
Gorman Maynooth 220	1	1	1	1					1
Gorman Louth 220		1	1						1
Corduff Drybridge 110		1	1	1					
Corduff Platin 110		1	1						
Gorman T2101		1	1	1					
Cashla Flagford 220		1	1						
Dalton Galway 110		1	1						
Athlone Shannonbridge 110		1							
Cashla Cloon 110		1							
Cashla Oldstreet 220		1							
Cashla Prospect 220		1							
Corduff Finglas 220 ckt 1		1							
Corduff Mullingar 110		1							
Gorman Navan 110 ckt 1		1							
Louth T2104 250 MVA		1							
Louth - Meath Hill 110									1
Oldstreet Woodland 400kV									1
Arva Flagford 220									1
Clashavoon Knockraha 220								1	1
Killonan Tarbert 220								1	1
Prospect Tarbert 220					1	1		1	1
circuit outages impacting transfers	6	19	10	4	4	5	3	6	10

Table: Circuits that should not be taken out for maintenance for various power transfers

Northern Ireland

In summer 2006, the Northern Ireland transmission system is relatively unaffected by maintenance and trip combinations at moderate power transfers. Only the outage of two Hannahstown 275/110kV transformers would result in a slight 1% overload on a 110kV circuit.

At larger power transfers, the Northern Ireland transmission system is sensitive to the outage of double circuit 275kV circuits. This is discussed elsewhere in this report.



Dublin Louth power corridor

The difficulties on this corridor form a significant barrier to power transfer from Republic of Ireland to Northern Ireland and are well known. On the Republic of Ireland system, there is very little generation north of Dublin. Yet, the load north of Dublin is quite significant. Consequently, the 220kV and 110kV lines heading north out of Dublin are already quite highly loaded. By 2006 winter, even without the additional strain of interconnector power transfers, there are N-1 overload problems on this part of the network. By 2006 summer; maintenance and trip outages of some of the circuits will overload the parallel circuits.

The key circuits are Gorman Maynooth 220, Louth Woodland 220, Corduff Platin 110, Corduff Drybridge 110 and Gorman T2101. Most of these circuits cannot be taken out for maintenance even for the no trade scenario. In practice, therefore, it is necessary to import power from Northern Ireland to allow the maintenance outage of any of these circuits to proceed.

The studies show that a number of other circuits in parallel with this route can also not be maintained while power is being transferred to Northern Ireland.

These circuits include

- Gorman Navan 110 circuits 1 and 2,
- Louth 220/110kV transformer,
- Cashla Flagford 220,
- Dalton Galway,
- Athlone Shannonbridge 110,
- Cashla Oldstreet 220 and
- Cashla Prospect 220.

Starting half-way up, there is a 110kV path that runs in parallel with the main 220kV route between Dublin and Northern Ireland. Associated with the large load in Navan, the Gorman Navan 110kV circuits are quite highly loaded. Loss of either Gorman Navan circuit (in combination with other circuits and power transfers to Northern Ireland) can overload the remaining circuit. This overload would increase with power transfer to Northern Ireland.

Separately, loss on maintenance and trip of both Gorman Navan 110kV circuits would result in Navan being tail fed on a long 110kV line from Arva. This would result in a local voltage collapse at Navan.

Corduff Finglas 220

With the large quantity of high merit generation in Dublin, there are difficulties associated with getting this power out of Dublin. Specifically, for the network as studied, when sending power to Northern Ireland, the loss of one Corduff Finglas 220kV circuit will significantly increase the loading on the parallel 220kV circuit. There are other 220kV circuits which, when tripped, slightly increase the load on the Corduff Finglas 220kV circuits. Combinations of one Corduff Finglas 220kV circuit with other circuits can overload the remaining Corduff Finglas 220kV circuit. This contingency is more significant at low load levels. At high loads, the Dublin load absorbs the output of the Dublin generation, whereas for the low load periods during the day, the excess power needs to get out of Dublin.

This consideration is no longer an issue for power transfer to Northern Ireland because the proposed connection for Huntstown 2 is a direct feed into Corduff.

Louth Tandragee 275kV double circuit and 275/220 transformers

The existing 275kV interconnector is connected to the Republic of Ireland system at Louth through three 275/220kV transformers. Two transformers are rated at 300 MVA, the third is rated at 600 MVA. Therefore, maintenance outages for which a further circuit trip would leave only one 300 MVA transformer connecting the Republic of Ireland and Northern Ireland systems cannot be accommodated during power transfers of 300 MW and greater.

The implications of a system separation, which would occur if both Louth Tandragee circuits tripped are dealt with elsewhere in this report.

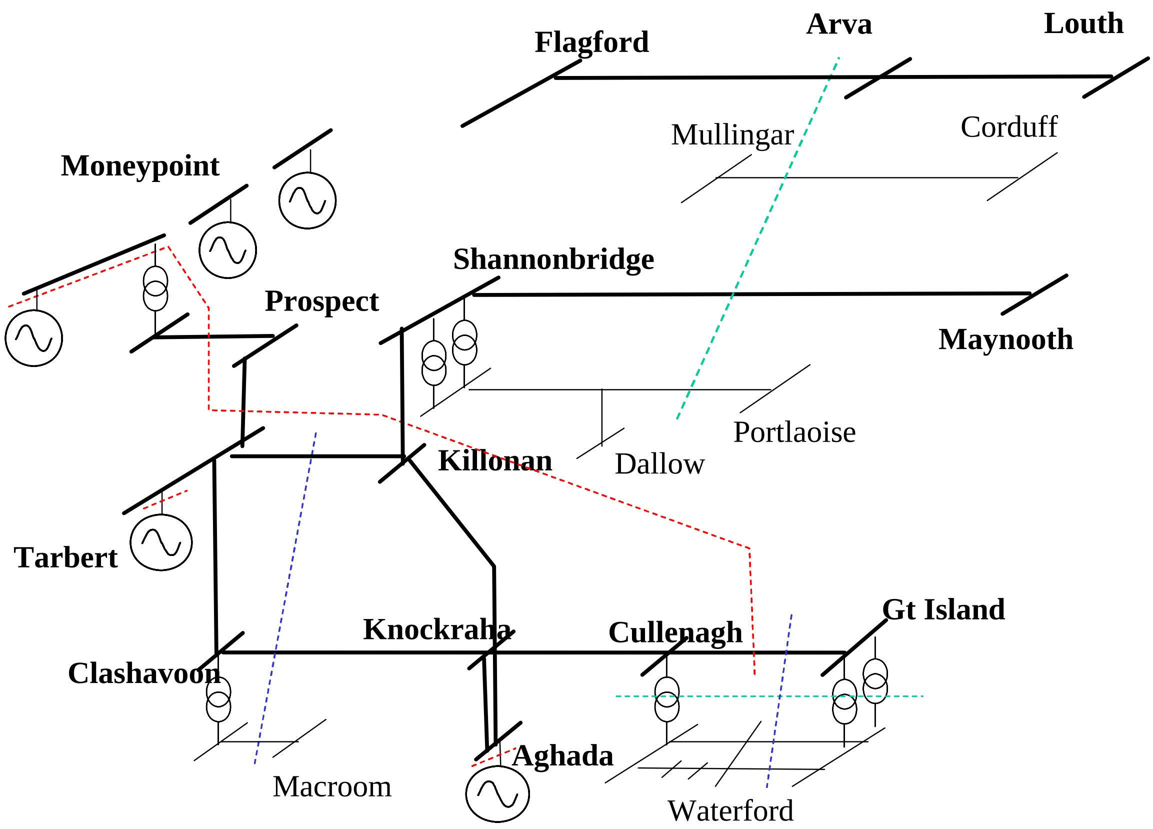
An additional interconnection provides additional transfer capacity at the border and will ease transfer restrictions.

Transfer to Munster

The studies also identified a number of maintenance and trip contingencies which cause problems in the extreme south of the network. Under maintenance conditions (including generator maintenance) these limit the quantity of power that can be traded between Munster and the rest of Ireland. The detailed results are provided below.

			Power to Northern Ireland				Power to Republic of Ireland				
outage 1	**outage 2**	**overload**	300 to Belfast .. Cor Lou 220 and Cor Fin 3 220	**300 to Belfast**	**150 to Belfast**	**no transfer**	**300 to Tarbert**	**600 to Tarbert**	600 to Tarbert Mpt Tarb 220 ard kill 110	**600 to Dublin**	900 to Dublin Arv Tyr 275 Gor MeHil 110
Aghada G1	Prospect Tarbert 220			-			**VC**	**VC**			
Killonan Tarbert 220	Clashavoon Knockraha 220	Clashavoon Macroom 110								5%	12%
Cashla Oldstreet 220	Moneypoint 3 (or Aghada gen)							**VC**			
Cashla Oldstreet 220	Cullenagh Great Island 220	Great Island Waterford 110						21%			
Cashla Oldstreet 220	Maynooth Shannonbridge 220	Portlaoise Dallow Shannonbridge 110						46%			
Cashla Oldstreet 220	Cullenagh Knockraha 220	Ballydine Cullenagh 110						9%			
Cashla Oldstreet 220	Gorman Navan ckt 1	Gorman Navan ckt 2						6%			
Cullenagh - Great Island 220	Aghada G1							**VC**			
Cullenagh - Great Island 220	Moneypont G3	Great Island Waterford 110						3%			
Cullenagh - Great Island 220	Prospect Tarbert 220							**VC**			
Cullenagh - Great Island 220	Killonan Shannonbridge 220	Great Island Waterford 110						14%			
Cullenagh - Great Island 220	Cullenagh Waterford 110	Killoteran Waterford 110						31%			
Cullenagh - Great Island 220	Great Island Waterford 110 ckt 1	Great Island Waterford 110 ckt 2						71%			
Maynooth Shannonbridge 220	Moneypoint 3 (or Aghada gen)							**VC**			
Maynooth Shannonbridge 220	Prospect Tarbert 220							**VC**			
Maynooth Shannonbridge 220	Cullenagh - Great Island 220	Portlaoise Dallow Shannonbridge 110						25%			
Maynooth Shannonbridge 220	Flagford Louth 220	Portlaoise Dallow Shannonbridge 110						18%			
Maynooth Shannonbridge 220	Cullenagh Knockraha 220	Portlaoise Dallow Shannonbridge 110						17%			
Maynooth Shannonbridge 220	Cashla 250MVA T2101	Portlaoise Dallow Shannonbridge 110						7%			
Maynooth Shannonbridge 220	Great Island Kellis 220	Portlaoise Dallow Shannonbridge 110						10%			
Maynooth Shannonbridge 220	Barrymore Knockraha 110	Ballydine Cullenagh 110						7%			
Prospect Tarbert 220	Aghada G1 or Tarbert G4							**VC**			
Prospect Tarbert 220	Killonan Shannonbridge 220							**VC**			
Prospect Tarbert 220	Cullenagh Knockraha 220	Great Island - Cullenagh 220 - 232 MVA					1%	**VC**			
Prospect Tarbert 220	Cashla Ennis 110							**VC**			
Prospect Tarbert 220	Dunstown Kellis 220							**VC**			
Prospect Tarbert 220	Arklow Great Island 220							**VC**			
Prospect Tarbert 220	Shannonbridge Ikerin 110							**VC**			
Prospect Tarbert 220	Arklow Carrickmines 220							**VC**			
Prospect Tarbert 220	other lines	low voltages						0.9pu			
Prospect Tarbert 220	Ennis Shannonbridge 110	Cashla Ennis 110						6% .. 0.86pu			
Prospect Tarbert 220	Ballydine Cullenagh 110							**VC**			
Flagford Louth 220	Cashla Oldstreet 220	Corduff Mullingar 110 - 93MVA 30% Arva Carrick-on-Shannon110 - 114MVA 7% Portlaoise Dallow Shannonbridge 110 - 76MVA 6% Arva Navan 110 -73 MVA 6% Maynooth Shannonbridge 220 - 294 MVA 3%						30%			

There is a minimum generation requirement in the south of the transmission system. However, one of the transfer scenarios involved reducing generation in the south of the network. Consequently it is not surprising that under these conditions, maintenance and trip outages can result in voltage collapse and / or serious overloads. With reduced generation in the south, maintenance and trip outage of any two of the following circuits will cause voltage collapse: Prospect Tarbert 220, Shannonbridge Killonan 220, Cullenagh Great Island 220 and Moneypoint Prospect 220.



Great Island – Waterford

The 220kV and 110kV circuits between Great Island and Cullenagh 220kV stations can get overloaded for maintenance and trip outages involving the circuits. The summer rating on the Great Island Waterford 220kV circuit is relatively low at 232 MVA. The line loadings on the circuits are influenced by generation dispatch. A reduction of generation in the south increases the loading on the circuits.

Maynooth Shannonbridge 220, Portlaoise Dallow Shannonbridge 110 and Corduff Mullingar 110

For increased power transfers to the south west, maintenance and trip outages involving circuits carrying power west across the country tend to overload the three circuits.

The ratings of these circuits are low; Portlaoise Dallow Shannonbridge 110kV and Corduff Mullingar 110kV have summer ratings of 72 MVA. Maynooth Shannonbridge 220kV has a summer rating of 285 MVA.

Local Problems

The studies identified a number of maintenance and trip contingency sets which cause problems on the network but which do not appear to be related to interconnector power transfer.

These problems are not included here.

Conclusion – Maintenance and Trip

A comprehensive set of results from the maintenance and trip studies is presented.

The major findings of the maintenance studies are as follows:

- The outage for maintenance of a number of circuits can limit available power transfer capability. The power corridor from Dublin to Louth is particularly restrictive. Reinforcement to this corridor would enhance power transfer capability.

- In some cases, the outage for maintenance of difficult circuits can only be facilitated by power import.

- Power from Northern Ireland cannot displace generation in the extreme south of the country. Local voltage and overload problems in the south mean that this trade cannot occur.

- There are a number of difficult maintenance and trip combinations which are unrelated to power transfer. These local problems are known to both system operators.

- Comparing the interconnector development options, Arva Tyrone 275, Coolkeeragh Srananagh 275 and the 110kV circuits, for the 2006 summer case, there is no significant difference in facilitating maintenance outage between the three options.

6 Fault Level

The fault levels on both the Republic of Ireland and Northern Ireland systems are quite high in some locations. It is important, therefore, that the impact of the interconnector development options on fault levels be investigated

6.1.1 Study Method

The generation dispatch method used in the fault studies is as follows.

The Automatic Sequencing Short Circuit Calculation (ASCC) function in PSS/E is used to generate a fault level summary for single phase to ground and three phase faults at each transmission bus. It is the RMS break fault current that is calculated using this method. The studies were performed using generator sub-transient reactance values. The generation dispatch and other assumptions used in the fault studies are listed below.

An alternative method for calculating fault current is the UK Engineering Recommendation G74. The main difference with this method is that the fault contribution from motors embedded in the load is included and a DC component of fault current is also included for fault make. It is expected that the relative increase of fault level will be the same regardless of whether ASCC or G74 is used.

Changes in generation dispatch (including decisions regarding the locating of new generation and whether or not to retire existing generation) will have a material impact on actual fault levels.

The 2006 / 7 winter study case is used as the basis for the undeveloped case for the fault studies.

It is assumed that the DC link to Scotland does not add any fault current. However, the transformers connecting the DC link to the 275kV network are earthed which does provide a path for zero sequence currents.

The following assumptions were made for future and / or retiring generation: -

Seven units are on in Ballylumford for the studies. These are

- Ballylumford Combined Cycle (units A, B and C)
- Ballylumford D
- Ballylumford 1 – 120 MW
- Ballylumford 5 – 200 MW
- Ballylumford 6 – 200 MW

Ballylumford units 2, 3 and 4 are not running in this study – they are presumed to be retired. In the study, it was assumed that for almost all the time, there would not be absolute maximum generation at Ballylumford. The open cycle gas turbines, units 7 and 8 are switched off. For occasions when they are on, the 275kV fault level at Ballylumford should be incremented by approx 350 amp per generator. The effect on other fault levels on the system is not significant.

For the 2006/7 winter study case, the Republic of Ireland system usually has a speculative generator at Maynooth in order to meet forecast demand. No speculative generator is running in this study. Instead, forecast demand is met with existing but low merit generation.

Apart from assumptions about generator availability and fault contribution from the DC link, detailed above, all generators were turned on in the case. Generation that is off in the original case is set to zero MW. This gives the worst expected fault current. This includes all embedded generation on the Republic of Ireland system.

6.1.2 Fault Level Results

Fault level studies were performed for a 2006/7 winter case with the different interconnector development options. Summary tables listing a selection of fault levels at transmission stations around the joint network are provided below. These show the increase in fault level due to the interconnector development options and compare expected fault level with the present switchgear rating.

6.1.3 Fault Level Conclusion

There is a small increase in fault level associated with each of the interconnector development options. The largest increase is at the stations where the interconnectors are located. In most cases they are within the peak break rating of the switchgear.

Those stations that exceed the 10% safety margin of fault level rating for one phase to ground are listed below. There are no violations of the safety margin for 3 phase.

Ballylumford 275	102% for all options
Inchicore 110	93% for all options
Louth 110	94% for 110kV option

The pre-existing single phase fault level is found to be high on the Dublin 110kV network and on the Northern Ireland 275kV network near Ballylumford but the fault levels are not materially increased by any of the interconnector development options. The high fault levels are already known to system operators and are managed by operational practice. Only the 110kV interconnector development option tends to dramatically increase fault levels on both networks, especially at Louth 110.

In conclusion, there appear to be minimal fault level implications associated with either of the 275kV interconnector development options.

Switchgear fault level and rating				**1 PHASE TO EARTH**			**Winter 2006/7**									
										2.00%			80.00%			
							Difference in Fault level						% on rating			
Name	Voltage	Rating	Basecase	110	Arva Tyrone	Cool Sran	110		Arva Tyrone		Cool Sran		Basecase	110	Arva Tyro	Cool Sran
	-----	Rating	A	A	A	A	A	%	A	%	A	%				
ESB																
ARVA	275	20000			5200				5200						26%	
LOUTH	275	20000	10431	10422	10436	10420	-9	-0.09%	5	0.05%	-11	-0.10%	52%	52%	52%	52%
SRANANA	275	20000				0					0					0%
ARVA	220	40000	4118	4113	7075	4202	-5	-0.13%	2957	71.79%	84	2.04%	10%	10%	18%	11%
CASHLA	220	40000	7884	7886	7983	8023	2	0.03%	99	1.25%	139	1.76%	20%	20%	20%	20%
FLAGFORD	220	40000	6617	6625	7292	7297	8	0.12%	675	10.20%	679	10.27%	17%	17%	18%	18%
FINGLAS	220	40000	35710	35833	35801	35762	124	0.35%	92	0.26%	52	0.15%	89%	90%	90%	89%
GORMAN	220	40000	9720	9747	9734	9717	27	0.27%	14	0.14%	-3	-0.03%	24%	24%	24%	24%
INCHICOR	220	40000	35781	35894	35865	35829	113	0.32%	85	0.24%	48	0.13%	89%	90%	90%	90%
IRISHTOW	220	40000	36790	36904	36875	36839	115	0.31%	85	0.23%	49	0.13%	92%	92%	92%	92%
LOUTH	220	40000	17468	17772	17789	17596	304	1.74%	321	1.84%	128	0.73%	44%	44%	44%	44%
SRANANAG	220	40000	3549	3552	3657	4510	2	0.06%	108	3.04%	961	27.07%	9%	9%	9%	11%
ARVA	110	25000	5703	5797	5708	5724	94	1.64%	5	0.09%	21	0.37%	23%	23%	23%	23%
CASHLA	110	25000	15097	15102	15204	15265	5	0.03%	107	0.71%	168	1.11%	60%	60%	61%	61%
CATH_FAL	110	25000	7589	7750	7615	7696	161	2.13%	26	0.34%	107	1.40%	30%	31%	30%	31%
CORRACLA	110	25000	4039	4054	4048	4054	15	0.38%	9	0.22%	15	0.37%	16%	16%	16%	16%
DUNDALK	110	25000	7849	8052	7826	7821	203	2.58%	-23	-0.29%	-29	-0.36%	31%	32%	31%	31%
FLAGFORD	110	25000	13626	13686	14053	14392	60	0.44%	427	3.13%	766	5.62%	55%	55%	56%	58%
FIN_URBA	110	26000	24125	24147	24141	24133	22	0.09%	15	0.06%	8	0.03%	93%	93%	93%	93%
FIN_RURA	110	25000	12368	12379	12368	12366	11	0.09%	0	0.00%	-3	-0.02%	49%	50%	49%	49%
INCHICOR	110	26000	26970	26998	26990	26981	27	0.10%	20	0.07%	10	0.04%	104%	104%	104%	104%
LOUTH	110	25000	22998	25543	23097	23007	2545	11.06%	99	0.43%	9	0.04%	92%	102%	92%	92%
LISDRUM	110	25000	3136	4898	3126	3128	1762	56.20%	-9	-0.30%	-8	-0.26%	13%	20%	13%	13%
LETTERKE	110	25000	6044	6664	6059	6071	621	10.27%	15	0.25%	28	0.46%	24%	27%	24%	24%
MULLAGHA	110	25000	7873	8083	7837	7831	211	2.68%	-35	-0.45%	-41	-0.52%	31%	32%	31%	31%
RATRUSSA	110	25000	6836	7073	6826	6832	237	3.46%	-11	-0.16%	-4	-0.06%	27%	28%	27%	27%
SHANKILL	110	25000	6566	6986	6560	6570	420	6.40%	-6	-0.09%	4	0.05%	26%	28%	26%	26%
SLIGO	110	25000	7855	7887	7945	8235	32	0.41%	90	1.15%	380	4.84%	31%	32%	32%	33%
SRANANAG	110	25000	9820	9883	9969	10531	64	0.65%	149	1.52%	711	7.24%	39%	40%	40%	42%
TRILLICK	110	25000	1642	2064	1646	1646	422	25.69%	4	0.23%	4	0.26%	7%	8%	7%	7%

Switchgear fault level and rating **1 PHASE TO EARTH** **Winter 2006/7**

										2.00%			80.00%			
							Difference in Fault level						% on rating			
Name	Voltage	Rating	Basecase	110	Arva Tyrone	Cool Sran	110		Arva Tyrone		Cool Sran		Basecase	110	Arva Tyro	Cool Sran
	-----	Rating	A	A	A	A	A	%	A	%	A	%				
NIE																
BAFD2-	275	19900	21816.7	21969.5	22080.2	21985.2	152.8	0.70%	263.5	1.21%	168.5	0.77%	109.63%	110.40%	110.96%	110.48%
COOL2-	275	19900	12842.8	12968.9	13011.1	13597.5	126.1	0.98%	168.3	1.31%	754.7	5.88%	64.54%	65.17%	65.38%	68.33%
MAGF2-	275	19900	15001.9	15126	15462.9	15270.6	124.1	0.83%	461	3.07%	268.7	1.79%	75.39%	76.01%	77.70%	76.74%
TANDRAGE	275	19900	17113.5	17287	17455.6	17217.2	173.5	1.01%	342.1	2.00%	103.7	0.61%	86.00%	86.87%	87.72%	86.52%
TYRN2-	275	31500	12089.9	12191.7	13093.3	12214.3	101.8	0.84%	1003.4	8.30%	124.4	1.03%	38.38%	38.70%	41.57%	38.78%
BAFD1-	110	22000	18794.3	18854.1	18889.3	18875.3	59.8	0.32%	95	0.51%	81	0.43%	71.73%	71.96%	72.10%	72.04%
COOL1-	110	39900	26688.4	27478.8	26826.4	27118.4	790.4	2.96%	138	0.52%	430	1.61%	66.89%	68.87%	67.23%	67.97%
DRUM1-	110	39900	21302.3	22819.8	21366	21441.2	1518	7.12%	63.7	0.30%	138.9	0.65%	53.39%	57.19%	53.55%	53.74%
DUNG1-	110	18400	14317.7	14576.9	14472.1	14392.7	259.2	1.81%	154.4	1.08%	75	0.52%	77.81%	79.22%	78.65%	78.22%
ENNK1_	110	18400	8044	8066.1	8071.3	8071.2	22.1	0.27%	27.3	0.34%	27.2	0.34%	43.72%	43.84%	43.87%	43.87%
LSMR1A	110	18400	9442.5	9545.9	9473.7	9515.7	103.4	1.10%	31.2	0.33%	73.2	0.78%	51.32%	51.88%	51.49%	51.72%
NEWY1A	110	18400	5713	9446.9	5750.7	5752.7	3734	65.36%	37.7	0.66%	39.7	0.69%	31.05%	51.34%	31.25%	31.26%
OMAH1-	110	39900	11210.9	11266.8	11276.6	11254.7	55.9	0.50%	65.7	0.59%	43.8	0.39%	28.10%	28.24%	28.26%	28.21%
STRA1-	110	18400	14647.5	14690.5	14705.3	14728.5	43	0.29%	57.8	0.39%	81	0.55%	79.61%	79.84%	79.92%	80.05%
TAND1A	110	31500	26438.6	29049.2	26427.5	26611.7	2611	9.87%	-11.1	-0.04%	173.1	0.65%	83.93%	92.22%	83.90%	84.48%
TYRN1-	110	31500	10556.7	10693.6	10689.5	10614.4	136.9	1.30%	132.8	1.26%	57.7	0.55%	33.51%	33.95%	33.93%	33.70%

Switchgear Ratings and Fault level 2006/7

3 PHASE TO EARTH

											2.00%					80%	
							Difference in Fault level						% of Rating				
voltage	bus	name	basecase	110	arva tyrone	Cool Sran	110		Arva Tyrone		Cool Sran		basecase	110	arva tyrone	Cool Sran	
			A	A	A	A	A	%	A	%	A	%					
ESB																	
275	1183	ARVA	0		6682				6682	n/a			0%		33%		
275	35231	LOUTH	10150	10119	10144	10111	-31	-0.31%	-6	-0.06%	-39	-0.38%	51%	51%	51%	51%	
275	5043	SRANANAG	0			4515					4515	n/a	0%			23%	
220	1182	ARVA	6132	6140	8857	6406	8	0.13%	2726	44.45%	274	4.47%	15%	15%	22%	16%	
220	1642	CASHLA	8110	8119	8282	8351	10	0.12%	172	2.13%	241	2.97%	20%	20%	21%	21%	
220	2522	FLAGFORD	6654	6680	7458	7801	26	0.38%	804	12.08%	1146	17.23%	17%	17%	19%	20%	
220	2562	FINGLAS	27093	27181	27166	27171	88	0.32%	72	0.27%	78	0.29%	68%	68%	68%	68%	
220	2842	GORMAN	10882	10983	10932	10913	101	0.93%	50	0.46%	32	0.29%	27%	27%	27%	27%	
220	3082	INCHICOR	27055	27152	27121	27128	97	0.36%	66	0.25%	73	0.27%	68%	68%	68%	68%	
220	3122	IRISHTOW	27204	27295	27265	27276	91	0.33%	61	0.22%	72	0.26%	68%	68%	68%	68%	
220	3522	LOUTH	16150	16454	16323	16249	304	1.88%	173	1.07%	98	0.61%	40%	41%	41%	41%	
220	5042	SRANANAG	3916	3926	4109	6239	10	0.26%	193	4.93%	2323	59.33%	10%	10%	10%	16%	
110	1181	ARVA	8006	8287	8062	8092	281	3.51%	56	0.70%	87	1.08%	32%	33%	32%	32%	
110	1641	CASHLA	11519	11528	11643	11710	8	0.07%	124	1.08%	191	1.66%	46%	46%	47%	47%	
110	1701	CATH_FAL	7477	7801	7512	7666	324	4.33%	36	0.48%	190	2.54%	30%	31%	30%	31%	
110	1981	CORRACLA	5578	5632	5588	5601	54	0.96%	10	0.18%	23	0.41%	22%	23%	22%	22%	
110	2101	DUNDALK	8440	8828	8471	8422	388	4.59%	31	0.36%	-19	-0.22%	34%	35%	34%	34%	
110	2521	FLAGFORD	10535	10613	10940	11363	78	0.74%	405	3.84%	827	7.85%	42%	42%	44%	45%	
110	2561	FIN_URBA	18780	18799	18796	18796	19	0.10%	16	0.08%	16	0.08%	72%	72%	72%	72%	
110	2571	FIN_RURA	14317	14367	14342	14333	50	0.35%	25	0.18%	17	0.12%	57%	57%	57%	57%	
110	3081	INCHICOR	19156	19179	19172	19172	23	0.12%	16	0.08%	16	0.08%	74%	74%	74%	74%	
110	3521	LOUTH	16873	18799	16980	16881	1926	11.41%	107	0.63%	8	0.05%	67%	75%	68%	68%	
110	3561	LISDRUM	4881	7686	4896	4876	2805	57.47%	15	0.31%	-5	-0.09%	20%	31%	20%	20%	
110	3581	LETTERKE	5912	7066	5911	5945	1154	19.52%	-1	-0.01%	33	0.56%	24%	28%	24%	24%	
110	4061	MULLAGHA	8714	9134	8747	8696	420	4.82%	33	0.37%	-19	-0.21%	35%	37%	35%	35%	
110	4781	RATRUSSA	6678	7042	6703	6683	364	5.45%	25	0.37%	5	0.08%	27%	28%	27%	27%	
110	4961	SHANKILL	7131	7800	7164	7156	669	9.38%	33	0.46%	25	0.35%	29%	31%	29%	29%	
110	4981	SLIGO	7344	7408	7489	8004	63	0.86%	145	1.97%	660	8.98%	29%	30%	30%	32%	
110	5041	SRANANAG	8197	8293	8378	9134	96	1.17%	181	2.21%	938	11.44%	33%	33%	34%	37%	
110	5361	TRILLICK	2771	5970	2770	2780	3200	115.48%	-1	-0.03%	10	0.34%	11%	24%	11%	11%	

Switchgear Ratings and Fault level 2006/7

3 PHASE TO EARTH

							2.00%								80%	
							Difference in Fault level						% of Rating			
voltage	bus	name	basecase	110	arva tyrone	Cool Sran	110		Arva Tyrone		Cool Sran		basecase	110	arva tyrone	Cool Sran
			A	A	A	A	A	%	A	%	A	%				
NIE																
275	70520	BAFD2-	17645	17702	17838	17685	57	0.32%	193	1.09%	40	0.23%	80%	80%	81%	80%
275	75520	COOLKEER	10734	10884	10896	11566	151	1.40%	163	1.51%	833	7.76%	54%	55%	55%	58%
275	85020	MAGF2-	15111	15265	15621	15438	154	1.02%	510	3.37%	327	2.17%	76%	77%	78%	78%
275	90020	TANDRAGE	15348	15520	15661	15382	172	1.12%	313	2.04%	34	0.22%	77%	78%	79%	77%
275	90320	TYRONE	12352	12475	13312	12460	122	0.99%	960	7.77%	107	0.87%	39%	40%	42%	40%
110	70510	BAFD1-	17189	17216	17260	17211	27	0.16%	71	0.41%	22	0.13%	66%	66%	66%	66%
110	75510	COOL1-	17721	18233	17790	17859	512	2.89%	68	0.39%	138	0.78%	44%	46%	45%	45%
110	77010	DRUM1-	17116	18793	17270	17160	1677	9.80%	154	0.90%	44	0.25%	43%	47%	43%	43%
110	77510	DUNG1-	12252	12575	12331	12280	323	2.64%	80	0.65%	29	0.24%	67%	68%	67%	67%
110	79010	ENNISKIL	5982	6017	5983	6007	35	0.58%	2	0.03%	25	0.42%	33%	33%	33%	33%
110	79016	ENNK_PST	4832	4859	4833	4807	27	0.57%	1	0.01%	-25	-0.52%	26%	26%	26%	26%
110	84411	LSMR1A	8781	8959	8795	8845	178	2.03%	14	0.16%	64	0.73%	48%	49%	48%	48%
110	86511	NEWY1A	5236	8360	5253	5249	3124	59.66%	17	0.32%	13	0.26%	28%	45%	29%	29%
110	87510	OMAH1-	9226	9304	9237	9247	78	0.85%	11	0.12%	21	0.23%	23%	23%	23%	23%
110	89510	STRABANE	10855	10888	10863	10876	33	0.30%	8	0.07%	21	0.20%	59%	59%	59%	59%
110	89516	STRA_PST	6995	7328	6991	7037	333	4.75%	-4	-0.06%	42	0.59%	38%	40%	38%	38%
110	90011	TAND1A	19096	21394	19287	19145	2298	12.03%	192	1.00%	49	0.26%	61%	68%	61%	61%
110	90310	TYRONE	10653	10890	10725	10679	237	2.22%	72	0.67%	26	0.24%	34%	35%	34%	34%

Notes

1. Ballylumford single phase fault level 19.9kA. Three phase fault level 22kA

7 Wind Generation

Both Northern Ireland and the Republic of Ireland have been identified by wind developers as an excellent location for wind farm development. It is necessary therefore to consider some of the aspects of wind generation that may impact on the case for an additional interconnection.

This section considers wind variability. A limited analysis is performed on the output of two similar 15 MW windfarms over a two month period. The windfarms are located in the north and south of the island respectively. Also, the impact of large quantities of wind generation locating near the border area in the Republic of Ireland is examined.

Finally, it is important that the resulting network with an additional interconnector should not be such that the system is more vulnerable following a single fault to widespread low voltages and subsequent disconnection of windfarms.

7.1.1 Wind Variability

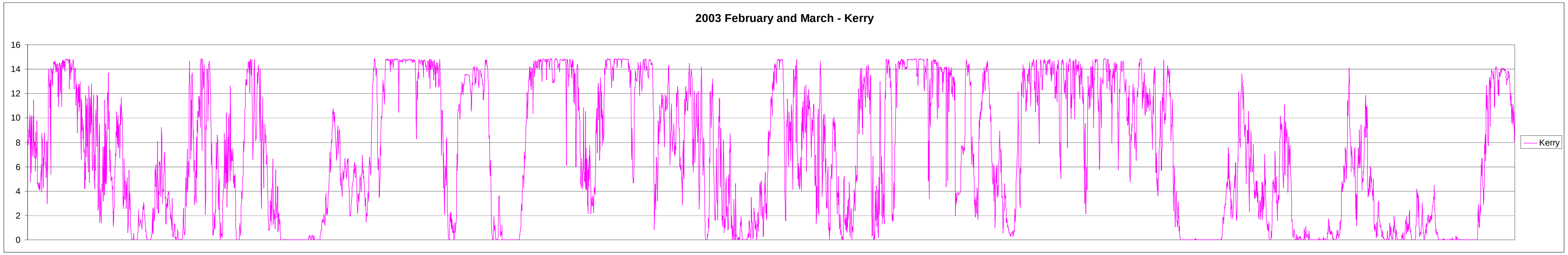
There is a contention by the wind industry that although the output from wind turbines and individual wind farms is variable, the average wind output spread over a larger area is much more consistent.

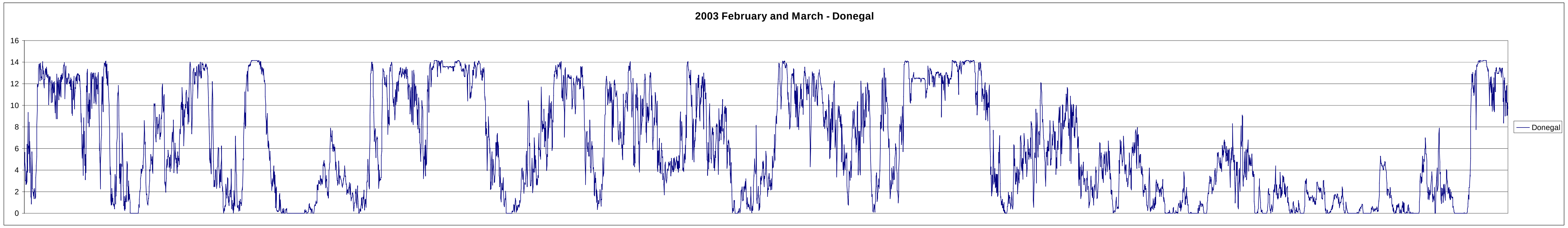
In order to examine the wind output at windfarms at both ends of the island of Ireland, data is compared for two 15 MW windfarms, one in the south of Ireland in Kerry and one in the northern part of Ireland, though still in the Republic of Ireland, in Donegal. The results give an illustration of the variation in wind production across the island of Ireland.

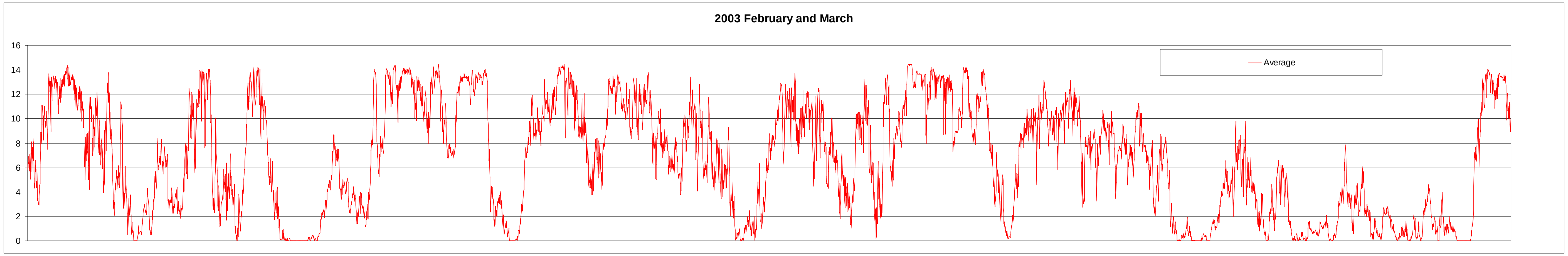
The power outputs are shown on the next page. The first two graphs show the output of the Kerry and Donegal 15 MW windfarms respectively. The third graph shows the average output. If the average power is desirable in both Kerry and Donegal, then it is necessary to transport the shared power from Kerry to Donegal. The fourth graph shows the amount of power that would be transferred from Kerry to Donegal in order to get the average output at both locations.

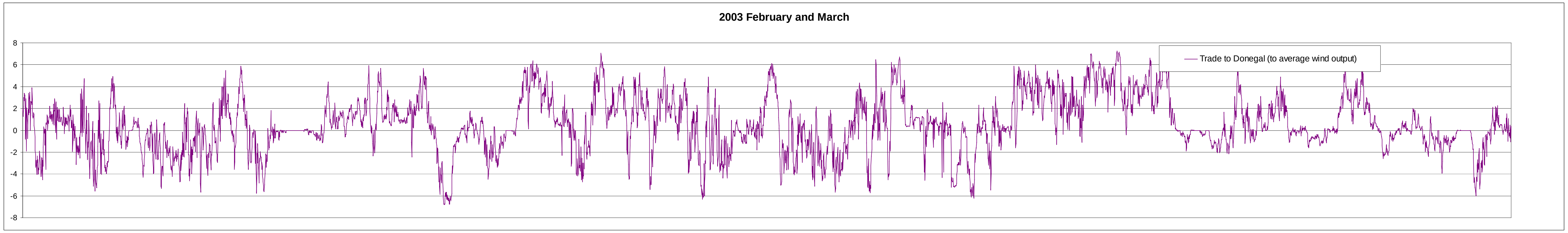
This data shows that there are times when power is generated in the south and not in the north and vice versa. If a similar relationship exists between windfarms in Northern Ireland and windfarms in the Republic of Ireland, then for those periods, interconnection is useful in balancing the windfarm output across the island of Ireland.

Prima facia, the data shows that there are times when power is simultaneously generated in both locations and times when power is not generated in both locations. So for significant periods of time, additional interconnection may be of little or no value. Since this work has been performed, analysis by Northern Ireland Electricity has shown that in general there may be scope for managing short term variability by transfers. That work indicates that in periods less than one hour there may often be scope for smoothing overall system variability using transfers.


2003 February and March - Kerry
16
14
12
10
8
6
4
2
0
Kerry


2003 February and March - Donegal
16
14
12
10
8
6
4
2
0
Donegal


2003 February and March
16
14
12
10
8
6
4
2
0
Average


2003 February and March
8
6
4
2
0
-2
-4
-6
-8
Trade to Donegal (to average wind output)

Interconnection may also prove useful in allowing wind generation in the Republic of Ireland access, through the Northern Ireland system, to the Scotland and England and Wales electricity markets.

It is important to note that the existing interconnection can already be used for these purposes.

As installed wind capacity continues to grow both in Northern Ireland and in the Republic of Ireland, there will soon come a time when installed wind capacity on both sides of the border is much larger than the declared interconnection transfer capacity, limiting the ability of the windfarm operators to share their generation commitments.

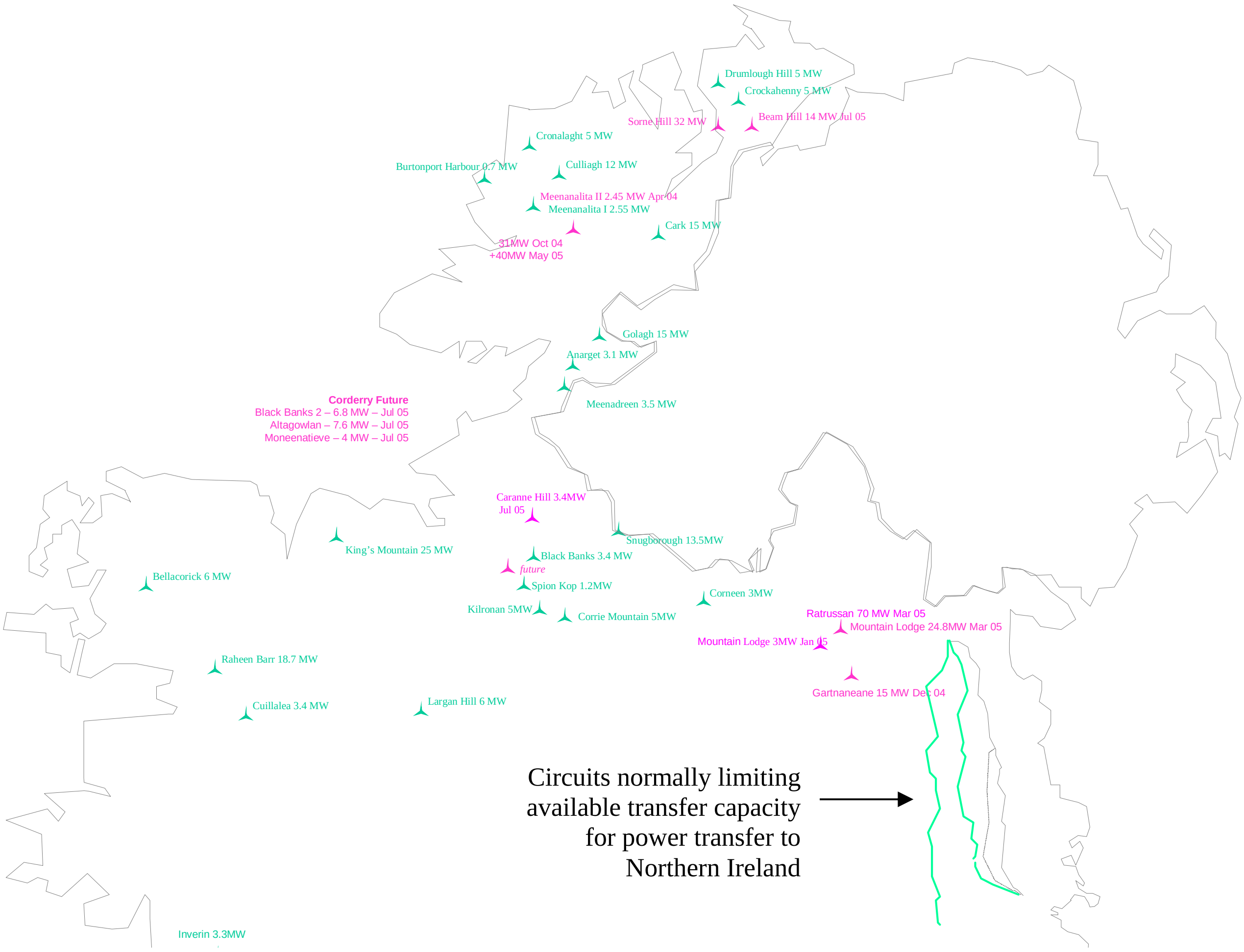
In summary, for some periods of time there may be some benefit for wind generators and wind developers in increasing interconnector capacity. Variability management is a stakeholder application for interconnector rather than technical performance. Therefore, this report does not attempt to quantify the benefit to wind generators of an increase in interconnector capacity. The ability to balance short term variability is however one factor in determining how much installed wind power system operators can manage with system security criteria.

Further studies will be required to assess the range of value which balancing energy might offer to stakeholders.

The study of penetration of windfarm power stations is the subject of separate work. It is however clear that high penetrations of wind generation will reduce the operating mass of traditional plant and could threaten system stability if the systems become isolated. Avoiding system separation may therefore become a precondition for larger amounts of wind generation on the island.

7.1.2 Wind Generation near Border

Transfer capability from the Republic of Ireland to Northern Ireland is limited by the ability of the transmission system in the republic to transfer power from Dublin, where there is a lot of generation, to the border. The 220kV and 110kV lines between Dublin and Louth are heavily loaded so that there is not much spare capacity for additional transfers for the purposes of exporting power to Northern Ireland. The key limiting circuits are Maynooth Gorman 220kV, Louth Woodland 220kV, Corduff Platin 110kV and Corduff Drybridge 110kV.



But, a significant portion of the prospective wind generation locating in the northern part of the Republic of Ireland is locating north of these circuits. The diagram below shows the existing (green) and prospective with connection offers (pink) wind generation in the Republic of Ireland. This wind generation (existing and prospective with connection offer) in the northern part consists of approx 300 MW of wind generation.

It can be considered that this generation may export to Northern Ireland without increasing the loading on the Dublin Louth transmission lines. Or, it could be stated that when this generation is running, there is a corresponding reduction in the loading on the circuits between Dublin and the border, allowing spare capacity for generation on the rest of the network to export power to Northern Ireland.

With an additional interconnection, the existing and proposed wind generation in the north east can be exported to Northern Ireland. The impact of any additional wind generation in the area, and whether that could successfully be exported to Northern Ireland will depend on its exact location on the transmission system. A consideration of the impact of speculative wind generation is outside the scope of this report.

This is an example of how interconnector transfer capacity can vary dramatically depending on the generation dispatch.

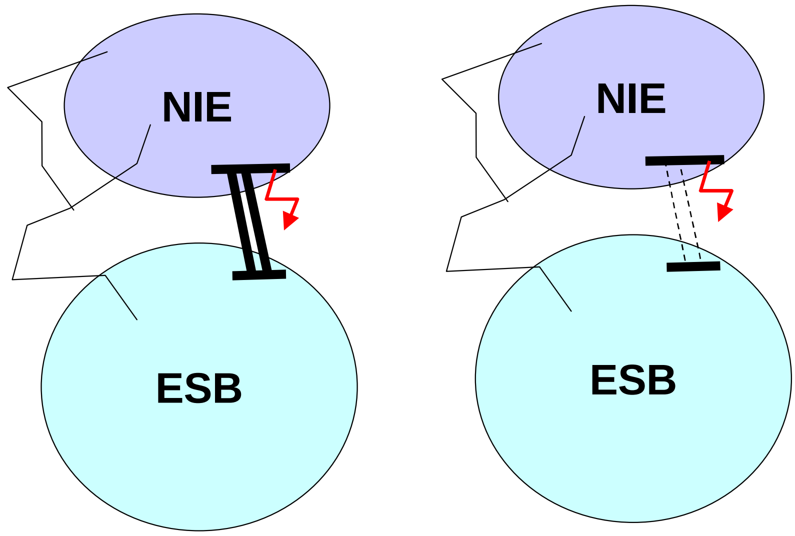
8 Transient Stability – Critical Clearance Time

It has been stated that the loss due to fault of the Louth Tandragee 275kV double circuit is a very serious contingency for the Republic of Ireland and Northern Ireland joint transmission system. For large power transfers, this double circuit contingency results in thermal, overload and dynamic stability problems.

As described above, an approach based on system separation is presently used to get around the problems. But for larger power transfers, system separation results in unacceptable frequency variations and, so, is not acceptable. Thus, additional interconnection is considered necessary if the Republic of Ireland and Northern Ireland systems are to safely engage in large power transfers.

Given the presence of transient stability problems in the existing network, it is important to quantify the transient stability situation for the proposed interconnector development options. In this section, an analysis technique called critical clearance time is used.

An investigation into the impact of future interconnection development options on dynamic stability is carried out. The Critical Clearance Time is a measure of the dynamic strength of the Republic of Ireland / Northern Ireland joint system. It is the longest time for which the system can be expected to survive a fault and still recover stability. The longer that the system can withstand a fault, the stronger the system is.



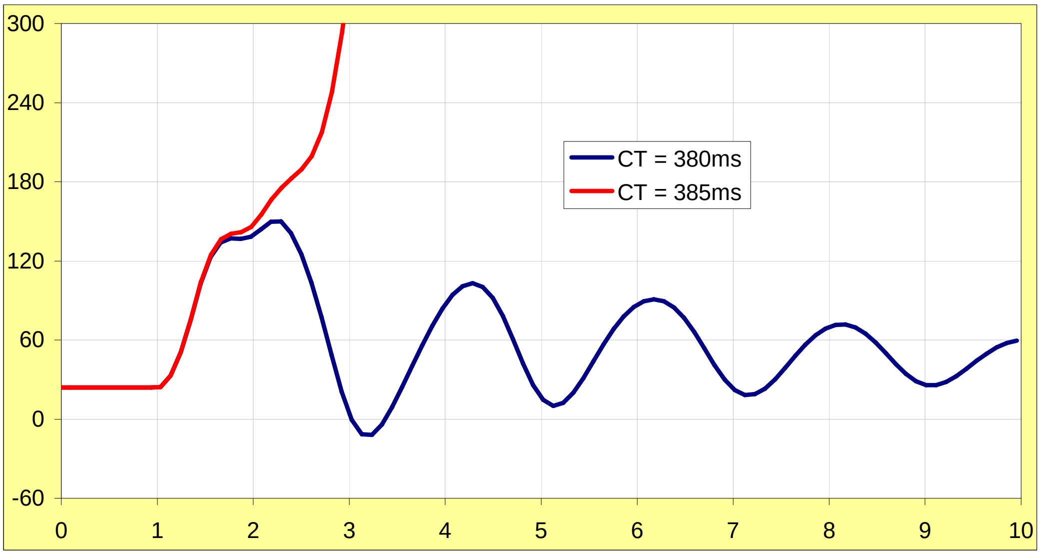
For the studies, a fault is simulated at the Tandragee end of the Louth Tandragee 275kV circuit. After a length of time, the simulated fault is cleared and the 275kV double circuit is tripped. This replicates how a fault would be cleared in a real system. In the study, the system is allowed to remain synchronised through the existing 110kV connections. The study is repeated for different values of fault duration until the duration is found for which the system goes unstable. I.e. the fault duration for which generators begin to lose synchronism is the critical clearance time.

This dynamic study considers power transfers between Dublin and Belfast and vice versa.

Example 1

Loading	0607 Winter Peak
Transfer	700MW to ESB
Option	275a+ (Arva-Tyrone 275kV with Basecase+ reinforcements)
Fault	275kV fault at Tandragee cleared by tripping the Louth-Tandragee 275kV double circuit.
CCT	380ms
Notes	For longer clearances, all NIE gens lose synchronism with ESB.

Ballylumford CCGT GA rotor angle (°) with respect to Turlough Hill



Notes

1. Fault instigation at t=1.0 secs.

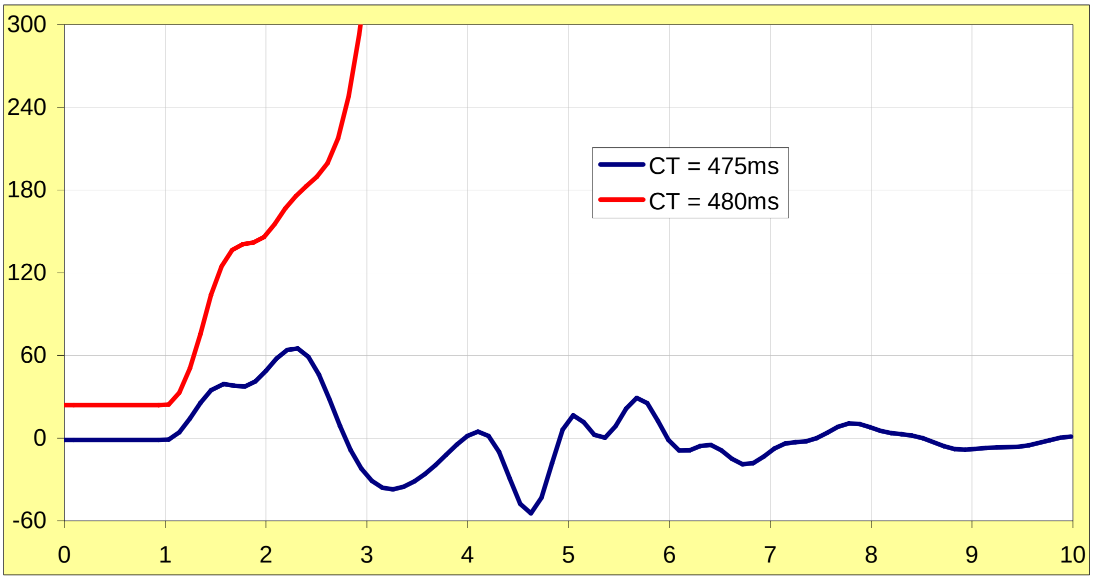
Two examples are shown. In example 1, the system remains stable for a simulated fault duration of 380 ms. There is some oscillation between Ballylumford and Turlough Hill, but, the oscillations are damped. Then, for a simulated fault duration of 385 ms, the system loses synchronism. After the fault, the angle at Ballylumford is unrelated to the angle at Turlough Hill. This study is performed for a transfer of 700 MW to Republic of Ireland, at winter peak 2006/07, with the Arva Tyrone 275kV reinforcement in place.

In example 2, the study is performed for zero transfer, at summer peak 2006, with no interconnector development reinforcement in place. The system remains stable for a simulated fault duration of 385 ms. There is some oscillation between Cathaleen's Fall and Turlough Hill, but the oscillations are damped. Then, for a simulated fault duration of 475 ms, the system loses synchronism. After the fault, the angle at Cathaleen's Fall is unrelated to the angle at Turlough Hill. The 2nd example is a bit unusual in that the system survives the first swing, but then some machines (Cathaleen's Fall) lose synchronism at the second swing. This is because the Cathaleen’s Fall machines experience opposing forces applied by the Northern Ireland and Republic of Ireland systems. At times, the forces combine to make the generation unstable relative to the remaining system.

Example 2

Loading	06 Summer Max
Transfer	0MW
Option	Base+ (No new interconnector, but with Basecase+ reinforcements)
Fault	275kV fault at Tandragee cleared by tripping the Louth-Tandragee 275kV double circuit.
CCT	475ms
Notes	For longer clearances, Cathleens Fall G3 loses synchronism.

Cathleens Fall G3 rotor angle (°) with respect to Turlough Hill



Notes

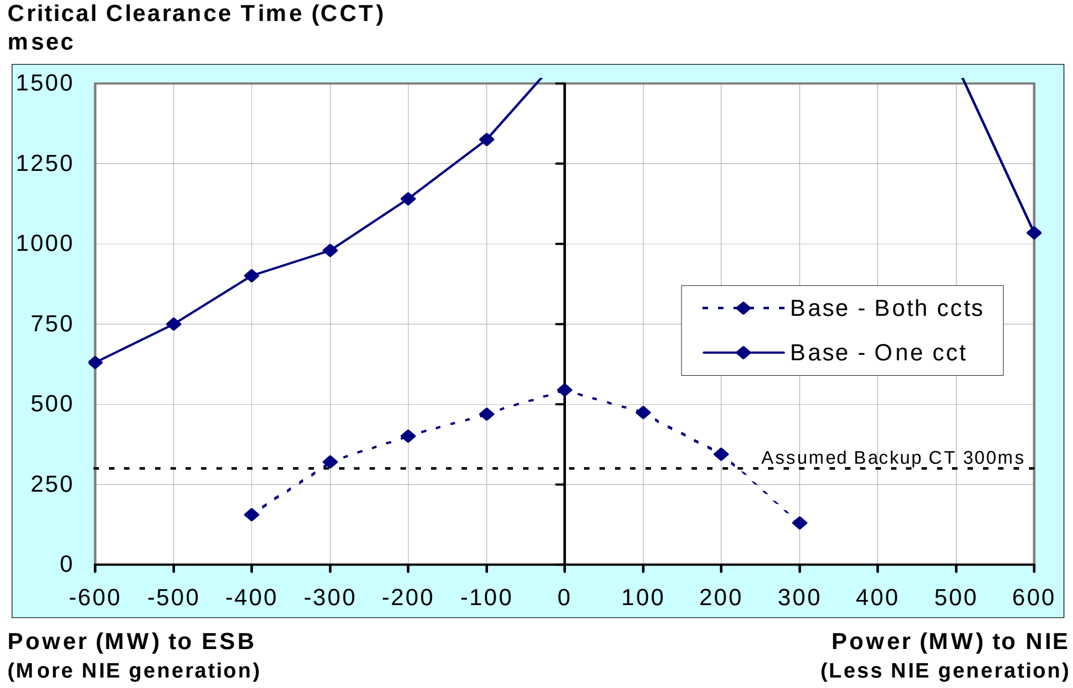
1. Fault instigation at t=1.0 secs.

These examples are designed as a theoretical way of showing relative system strength. In reality, special protection schemes are used to prevent networks from remaining connected.

By finding the critical clearance time for different power transfers between ESB and NIE, it is possible to determine the relative strengths of the interconnector development options under consideration. Plots of critical clearance time against interconnector trade are shown on the next few pages. A critical factor is the response time of the protection on both networks. There is a reasonable expectation that all faults will be cleared in "second step" or approx. 300 ms. This value is shown on the graphs. This process is repeated for each of the interconnector development options and for a large number of power transfers. A series of graphs is shown. These compare the effects of the impact of the interconnector development options with the existing interconnection capability to withstand the loss of the Louth Tandragee 275 double circuit and remain stable as a joint system. It is assumed that the back up clearance time of the protection is 300ms.

8.1.1 Single Circuit v. Double Circuit

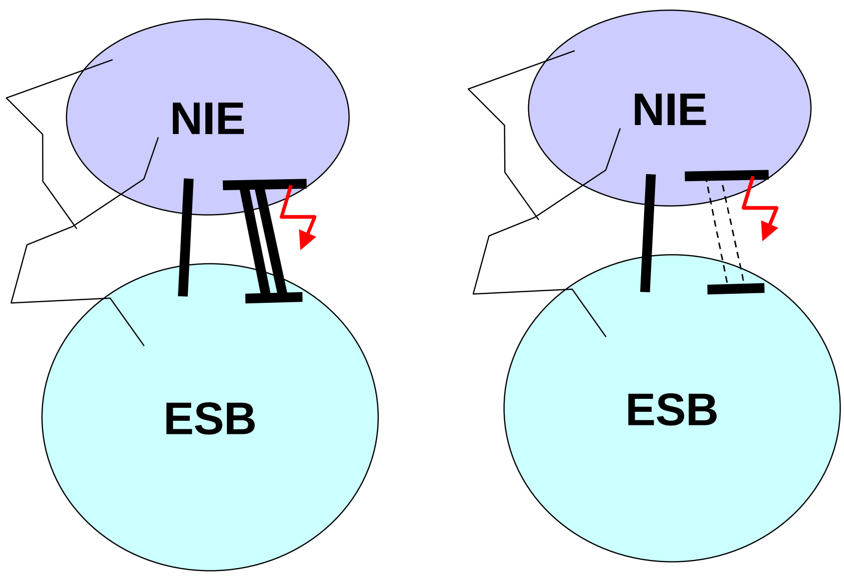
Trip of Louth Tandragee 275 single circuit following fault at Tandragee 275kV bus (2006/7 Winter Maximum)



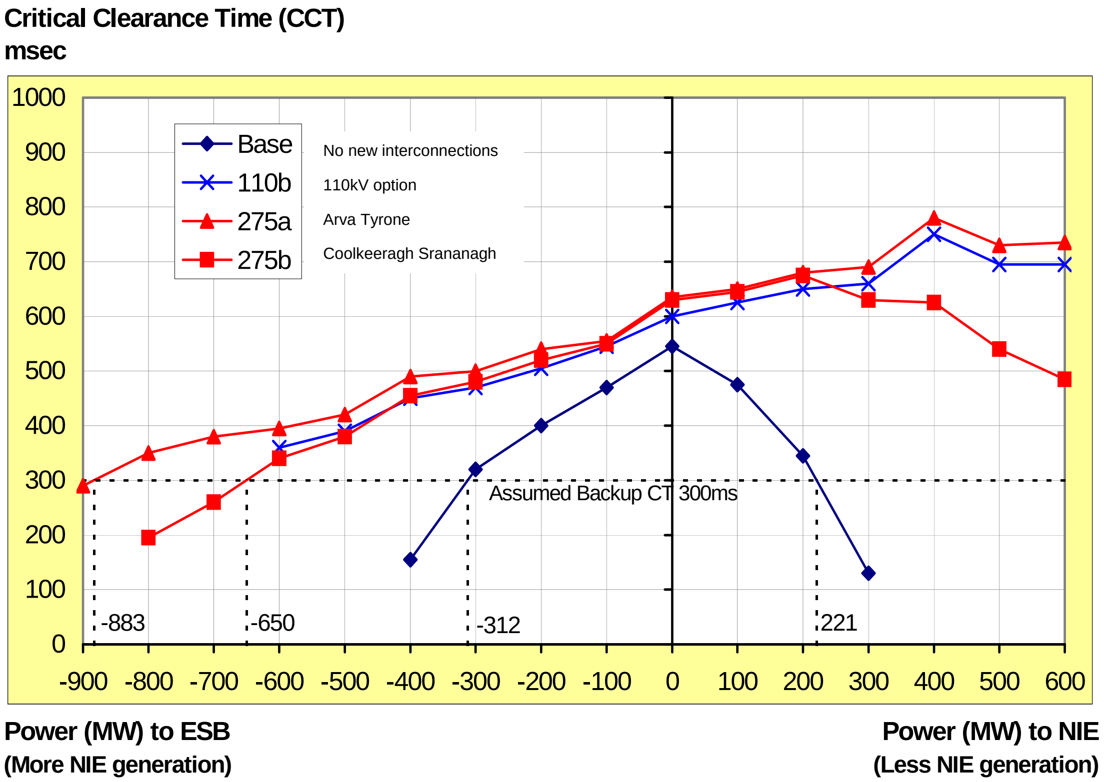
For the fault and loss of one circuit of the Louth Tandragee 275 double circuit, there is no problem.

8.1.2 Interconnector Options

It is to be expected that additional interconnectors would improve the dynamic performance of the network because, as illustrated in the graphic below, the loss due to fault of the existing Louth Tandragee 275kV double circuit should still leave the two systems connected on a relatively strong interconnection.



Trip of Louth Tandragee 275 double circuit following a fault at Tandragee 275kV bus (2006/7 Winter Maximum)

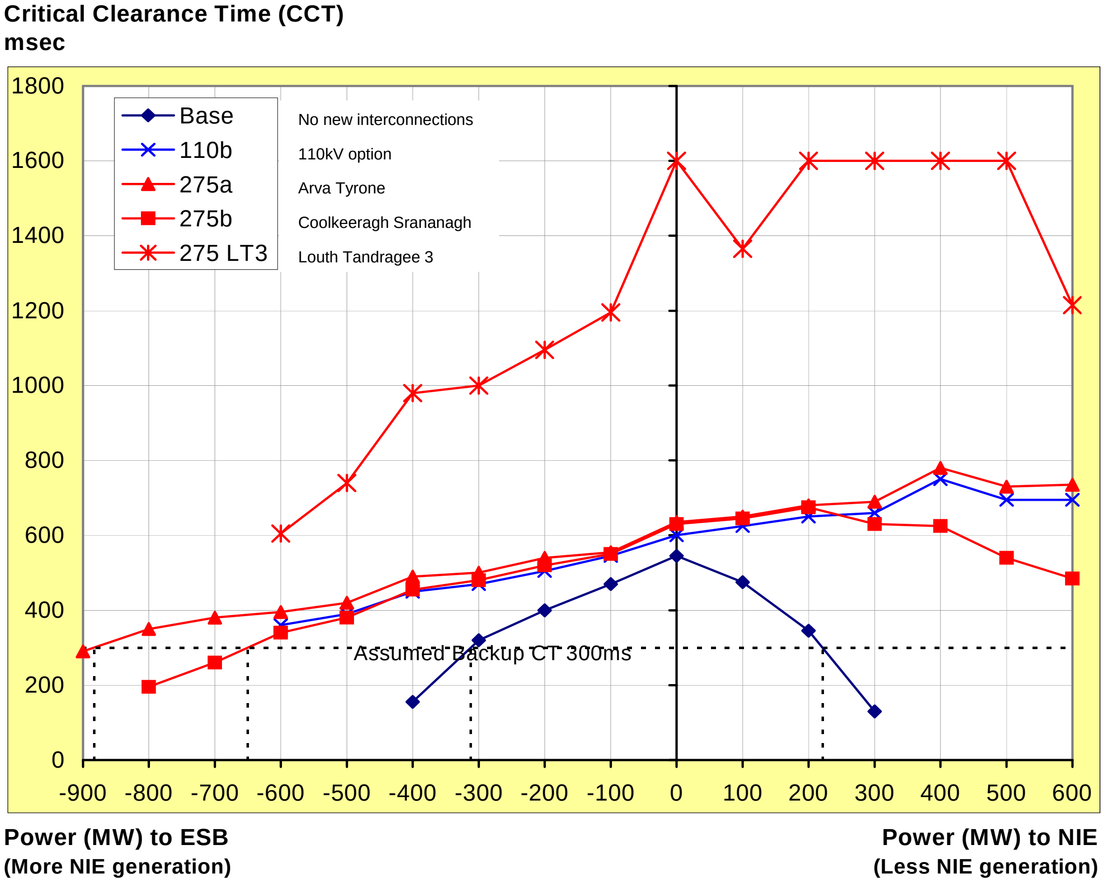


The dynamic studies indicate that an additional interconnector option will provide greater stability for the system in the event of a fault causing the trip of the Louth Tandragee 275kV double circuit. The 275kV Arva Tyrone interconnector development option is better than the 110kV options however they are both acceptable for large transfers.

Arva Tyrone 275 gives the best dynamic performance of the options under consideration. Coolkeeragh Sranangh 275 gives slightly diminished performance for high transfers in either direction but is still satisfactory for 650 MW power transfer.

The 110kV option, behaves almost as well as the 275kV options. This is because the 110kV circuits are in parallel with the Louth Tandragee 275kV double circuit and offer a short path to the synchronising power flows. This excellent dynamic performance is undermined by the fact that the 110kV interconnectors would be thermally overloaded for moderate power transfers.

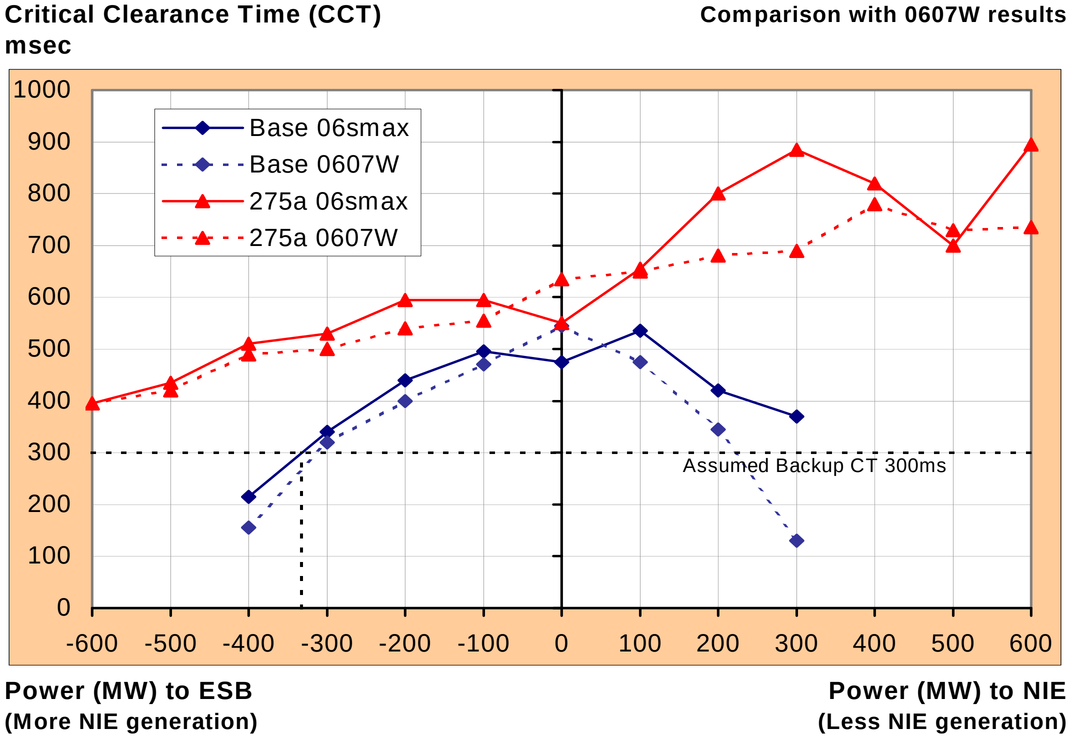
The general shape of the traces shows poorer system performance for power transfers to ESB. It is possible that the poorer performance may occur when there is more generation on the NIE system, all of which is electrically close to the fault. More generation being close to the fault would result in a larger shock to the system.



Louth Tandragee 3 275kV circuit shows a better transient stability performance than the other options under consideration.

8.1.3 2006/7 Winter Peak v 2006 Summer Peak

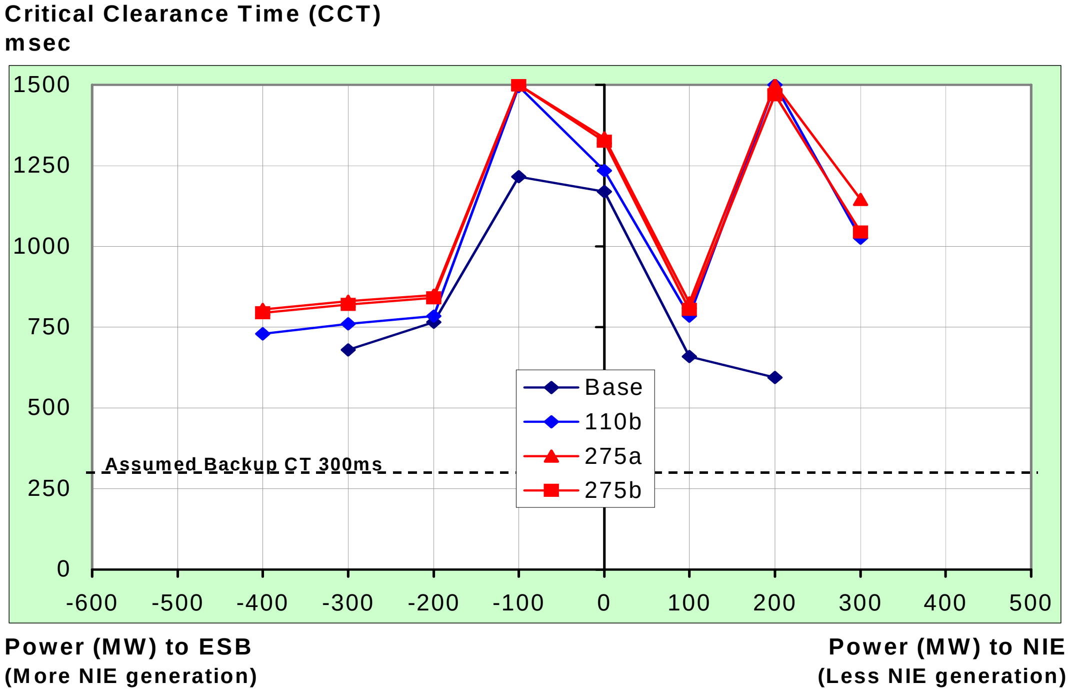
Trip of Louth Tandragee 275kV double circuit following a fault at Tandragee 275kV bus



The summer peak and winter peak results are quite similar (above). There appears to be no dynamic problems for a credible range of power transfers at summer night valley (below).

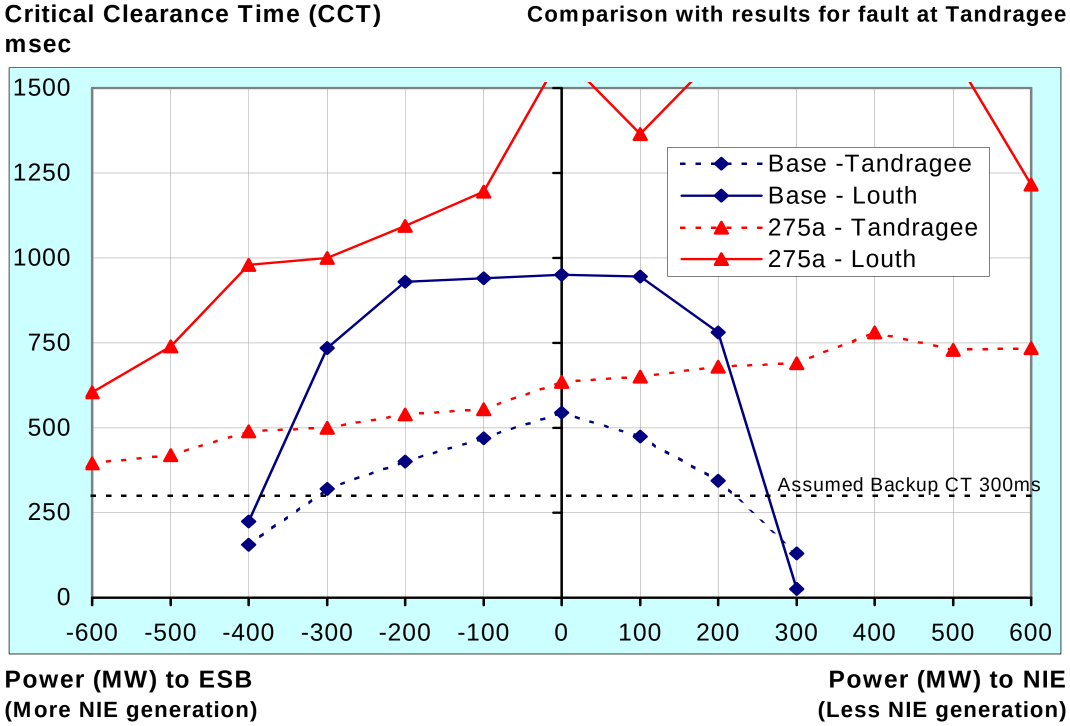
8.1.4 2006 Summer Night Valley - Minimum

Trip of Louth Tandragee 275 double circuit following a fault at Tandragee 275kV bus



8.1.5 Fault at Tandragee 275kV v. Louth 220kV

Trip of Louth Tandragee 275 double circuit following fault at Louth 220kV bus (2006/7 Winter Maximum)



Finally, a fault and trip of the Louth Tandragee 275kV double circuit is worse when the fault originates at the Tandragee 275kV side than the Louth 220kV side of the interconnector. Presumably, this is because the strength of the disturbance is related to the relative nearness of the Northern Ireland generation to the fault. When the fault is at Tandragee 275kV, this is electrically close to the NIE generation and acts as a large disturbance to the system. Conversely, a fault at Louth 220kV is electrically further from generation in both systems and so is easier on the joint system.

8.1.6 Conclusion

In conclusion, from the dynamic studies of the critical clearance times following a fault and the trip of the Louth Tandragee 275kV double circuit, the joint systems reach stability limits for low levels of transfer. For any of the additional interconnector options being considered, this stability limit is not reached until a larger transfer level takes place. All the interconnector options provide better dynamic performance although Arva Tyrone provides the largest range of power transfer. It is believed that the thermal limits will be reached with the 110kV option before the stability limits are reached.

Comparing the fault location between Louth and Tandragee is found that the worst fault location is at Tandragee.

9 Small Signal Stability

An independent assessment of the small signal performance of the joint network was commissioned. This work was performed by Prof. John Smith of Strathclyde University. The work consisted of two parts. The first part is to examine the network for potential small signal oscillation problems at the range of power transfers of interest to this investigation. The second part is to consider the merits of various stability monitoring tools.

The small signal stability report is attached as an appendix to this report.

As regards the small signal stability of the joint network, Prof. Smith performed a dynamic simulation analysis of the network using PSS/E for a range of contingencies and also performed an eigenvalue analysis.

The findings of the report are that for the range of power transfers under consideration, there appear to be no small signal stability problems. Even after a serious contingency, any oscillations that occur are quite well damped.

The report does comment on the interaction of wind with system dynamics. At the time of the study, the wind simulation models were not well understood and Prof. Smith expressed concern as to how the system might perform with large amounts of wind. The report also noted that in Ireland, wind is locating in the weak parts of the network and offered the comparison that other countries are reinforcing their networks to accommodate wind.

In summary, nothing discovered so far indicates that an additional 275kV interconnection will cause problems. On the contrary, an additional interconnection will strengthen the links between the two networks and improve stability.

10 Summary and Conclusion Technical Study Apr 2001 to Jul 2004

Comparison of Additional Interconnection Options

A suite of technical studies were undertaken jointly by a team of engineers from ESBNG and NIE over the period April 2001 to July 2004. The purpose of the technical studies is to perform a comparison of the proposed interconnector development options. The impact of the different interconnector options was assessed on fault level, transfer capability, small signal stability and transient stability.

The performance of the transmission networks for the different interconnector development options is summarised in the table below.

	Existing	**110 option**	**Western** **Coolkeeragh Srananagh 275**	**Mid Country** **Arva Tyrone 275**	**Eastern** **Louth Tandragee 275**
System Separation RAS	**On**	Off	**Off**	**Off**	Residual Risk
geographic separation		Some	Yes	Yes	No
Fault Level		Minimal increase	Minimal increase	Minimal increase	Minimal Increase
System Separation Limit	to ESB 460 to NIE 295				Risk of separation to ESB 460 to NIE 295
Transient Stability Limit loss of Louth Tandragee 275kV double circuit		600+ to ESB 600+ to NIE	650 to ESB 600+ to NIE	900+ to ESB 900+ to NIE[30]	900+ to ESB 900+ to NIE
Loadflow Limit [31] to ESB to NIE	N/A	400 350[32]	788 354[33]	727 721[34]	544 633[35]
Length	Louth Newry 40km Lisdrum Tandragee 35km Coolkeeragh Trillick 20km 95 km		125km	82km	50km

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30 Severe MVAr requirements for power transfers greater than 600 MW

31 overloads at the border for winter worst of N-1 and N-DC. Reinforcement of the internal transmission networks in Ireland and Northern Ireland would be required to accommodate these flows.

32 loss of Louth Tandragee 275 DC => overload Louth Newry 110 (s-n)+ and (n-s)

33 loss of Louth Tandragee 275 DC => overload Arva Gortawee 110 (s-n) and Corraclassy Enniskillen 110 (n-s)

34 loss of Louth Tandragee 275 DC => overload Arva Gortawee 110 (s-n) and Arva 600 MVA (n-s)

35 loss of Louth Tandragee 275 DC => overload Louth 600 MVA (s-n) and (n-s). With larger transformer capacity in Louth (and the risk of simultaneous loss of all interconnector circuits was considered acceptable), this capability would increase.

The transfer capabilities quoted are for power transfers between Dublin and Belfast and vice versa. These transfer capabilities are based on the assumption that additional internal reinforcements are presumed to be implemented on both networks.

At the transfer levels studied and for the existing generation mix, there appears to be no small signal or transfer stability issues.

The 110kV multi-line interconnector raises 110kV fault levels at both Louth and Tandragee. The fault level implications of the different 275kV interconnector options are similar.

The findings of the investigation into transfer capabilities are as follows.

With the existing network, for the loss of the existing double circuit 275kV interconnector, a remedial action scheme is in place to trip the 110kV interconnectors and separate the two systems. This is done to protect the 110kV interconnector circuits from damage. This system separation is acceptable for moderate power transfers but for higher power transfers, this system separation poses an unacceptable shock to the respective transmission systems. Hence, system separation is a major factor limiting power transfer between Northern Ireland and the Republic of Ireland. The system separation transfer limit is more restrictive at periods of low demand.

The possibility of using 110kV interconnectors, on their own, to increase interconnection between Northern Ireland and the Republic of Ireland is ruled out. At moderate power transfers, the loss of the Louth Tandragee 275kV double circuit would overload both the proposed 110kV interconnector circuits and other 110kV circuits on both systems. This does not rule out the construction of an additional 110kV interconnector at some future date in order to provide local benefits or supplement the 275kV performance.

The following table shows the transfer capabilities of the existing network and the transfer capabilities for the mid-country and western 275kV interconnector development options. These are for Arva Tyrone 275kV and Coolkeeragh Srananagh 275kV respectively. The transfer capabilities are quoted for power transfers between Dublin and Belfast and vice versa and are made on the basis that additional internal reinforcements are implemented. The existing transfer capability is limited by the system separation limit.

	Power to Republic of Ireland Belfast to Dublin			Power to Northern Ireland Dublin to Belfast		
	Winter Peak	Summer Peak	Summer Night Valley	Winter Peak	Summer Peak	Summer Night Valley
Existing	460[36]	450[37]	120	295	240	144
Mid Country: Arva Tyrone 275	727	770	>600	721	564	>500
Western Option: Coolkeeragh Sranangh 275	788	682	>600	354	275	300

A graphical presentation of this information is as follows. The pink line represents the existing system, the red line represents a western 275kV interconnection and the blue line represents the mid country option.

The x-axis represents transfer capability. Negative numbers represent power transfer to the Republic of Ireland and positive numbers represent power transfer to Northern Ireland. The y-axis represents system demand. It is appropriate to represent the transfer capability information in terms of system demand because power transfer capabilities vary with system demand.

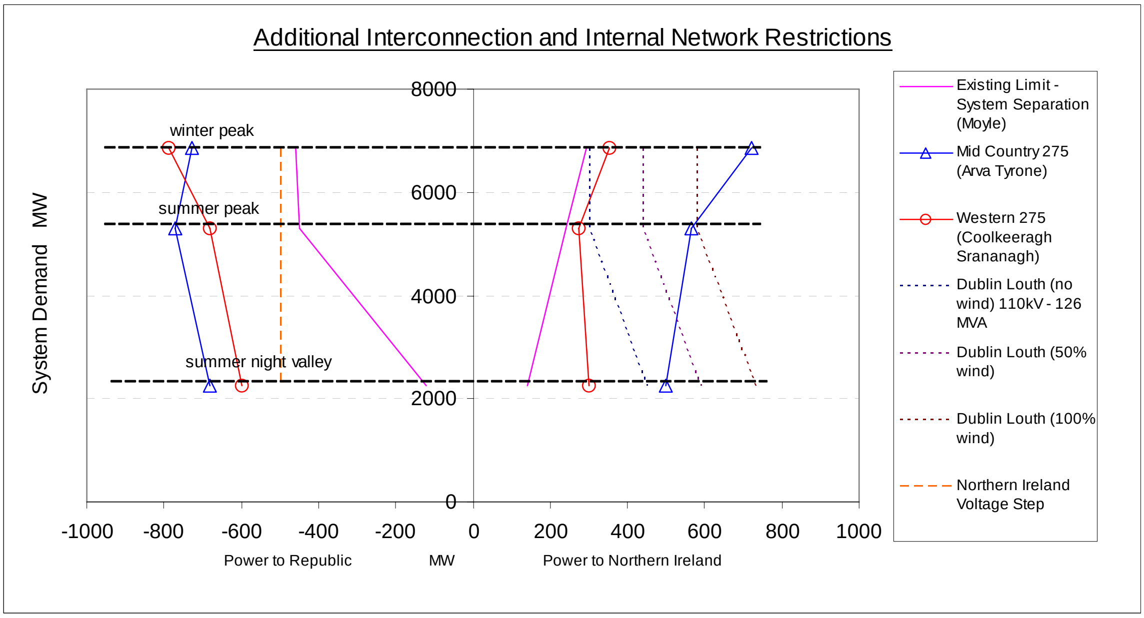
36 Depending on import from Moyle
37 Depending on import from Moyle

For power transfer from Belfast to the Republic of Ireland, both 275kV interconnectors give similar performance. However, for power transfer from Dublin to Northern Ireland, the Arva Tyrone 275kV interconnector gives superior performance. The realisation of this superior south to north transfer capability will depend on the generation dispatch in the Republic and on whatever reinforcement programme may be selected for the Dublin Louth corridor.

Some other 275kV options that might be considered, such as an eastern 275kV interconnector (third Louth Tandragee circuit 275kV) or other mid-country options from Tyrone to the ESB 220kV network, such as Tyrone Kingscourt 275kV have been examined and give similar technical performance to Arva Tyrone 275kV.

Internal Network Restrictions

It is possible to superimpose the internal network restrictions on representation of the capabilities of the interconnector options. This illustrates the impact of generation dispatch on the transfer capability and shows where additional reinforcement will be required to maximise the impact of the additional interconnection.



For power transfer from south to north, the main restriction is the capability of the Dublin Louth corridor to carry additional power to the border. In the studies, with the Corduff Drybridge 110 and Corduff Platin 110kV lines rated at 126 MVA, it is found that the network would allow only slightly more power transfer than the existing system separation limit. The realisation of the south to north transfer capability provided by the additional interconnector depends on the generation dispatch in the Republic and on whatever reinforcement programme may be selected for the Dublin Louth corridor.

For power transfer from north to south, the main restriction is the risk at large power transfers of a large voltage step on the Northern Ireland network caused by the loss of the 275kV double circuits between Ballycronan More and Hannahstown. It is likely that a large SVC at Castlereagh 275kV station would solve this problem.

Conclusion

A suite of technical studies were undertaken jointly by a team of engineers from ESBNG and NIE over the period April 2001 to July 2004. Technical studies compared the performance of a number of interconnector development options. These are

- 110kV multi-circuit option
- Western 275kV (assumed to be Coolkeeragh Strabane 275kV for the purpose of these studies)
- Mid Country 275kV (assumed to be Arva Tyrone 275kV for the purpose of these studies)
- Eastern 275kV (i.e. third Louth Tandragee 275kV circuit)

The studies found that the 110kV multi-circuit option does not provide a significant increase in transfer capability and is therefore not technically acceptable.

The eastern option, the third Louth Tandragee 275kV circuit would offer increased power transfer capability in both directions but there are concerns about the risk of all main interconnections terminating in both Louth and Tandragee. Also the routes of the new and existing 275kV circuits might not be sufficiently separate to be unaffected by the same events. The implication is that Louth Tandragee does not actually solve the system separation problem. In these circumstances, Louth Tandragee does not increase the transfer capability and is therefore not a technically acceptable option.

The western option, Coolkeeragh Srananagh 275kV increases power transfer to Republic of Ireland, facilitates power transfer out of Coolkeeragh and helps support the 220kV network in the north west of the Republic of Ireland. However, the transfer capacity to Northern Ireland is poor compared with the other 275kV interconnector options.

The mid-country option, Arva Tyrone 275kV, offers increased transfer capability in both directions. It offers physical and geographical separation from the existing interconnection, thereby eliminating the risk of the system separation.

Based on these technical studies, carried out between April 2001 and July 2004, the mid-country option is the preferred option. A decision on whether to progress an interconnector will depend on an economic analysis and on regulatory input. A final decision on which interconnector option to progress will depend on a pre-feasibility of the route corridor and assessment of other factors.

In addition to any proposed additional interconnection, internal network reinforcement may be required in order to maximise the benefit of the additional interconnection. Reinforcements include reinforcing the Dublin Louth corridor and locating a large SVC in Northern Ireland, possibly at Castlereagh 275kV station.

Appendix 1 – 2006/7 Winter Results Loadflows

The transfer capabilities are calculated from an analysis involving distribution factors and DC loadflow. It is worth noting that some of the declared transfer capabilities are less significant than others. That is because at present there may not be sufficient generation at the sending end for this to be a network constraint. For example, the quantity of generation at Cashla, Shannon and Coolkeeragh is not enough to meet both local load requirements and reach the transfer limits identified in these studies.

The transfer capability of the Republic of Ireland transmission system is restricted almost exclusively by N-1 problems. The impact of an additional interconnector in getting power across the border is defined by the N-DC performance figures. Problems on the Northern Ireland system appear to be both N-1 and N-DC in nature. Some of the Northern Ireland problems are mitigated by remedial action schemes.

2006/7 Results - Power to Republic of Ireland

The transfer capabilities calculated for power transfer to Republic of Ireland for 2006/7 winter are as follows.

Existing

2006/07 Winter - basecase+						No additional interconnection			
Transfer				NI System[38]		Interconnections		RoI System[39]	
From	To	Ref		N-1	N-DC	N-1	N-DC	N-1	N-DC
Derry	Dublin	1	3	453	174[40]	657	450[41]	1104	450[42]
Belfast	Dublin	2	3	1082	450	657	450	1104	450
Derry	Shannon	1	5	453	174	657	450	531	450
Belfast	Shannon	2	5	1082	450	657	450	531	450

The system separation limit for power transfer to Republic of Ireland is 450 MW (depending on Moyle import value).

Shaded boxes:- The presence of a remedial action scheme whereby on loss of the Louth Tandragee, the systems separate tends to protect both the other interconnector circuits and the circuits in the Republic of Ireland from the transmission implications

[38] This study was performed with an intact 110kV network. NIE occasionally sectionalise the 110kV network which could affect the transfer capability

[39] presuming the Republic of Ireland system is reinforced with a Corduff Louth 220kV circuit

[40] overload Coolkeeragh Strabane 110 165 MVA for loss of Coolkeeragh Magherafelt 275kV double circuit

[41] Without system separation, would overload Corraclassy Enniskillen 110 for loss of Louth Tandragee 275kV double circuit

[42] Without system separation would overload Corraclassy Gortawee 110 for loss of Louth Tandragee 275kV double circuit

of the loss of Louth Tandragee 275kV double circuit. The impact of system separation on restricting power transfers is discussed in section 6.

Louth Tandragee 275kV 3rd circuit

Power to Republic of Ireland

2006 / 07 Winter - 275kV Option C+						Louth Tandragee circuit 3			
Transfer				NI System[43]		Interconnections		RoI System[44]	
From	To	Ref		N-1	N-DC	N-1	N-DC	N-1	N-DC
Derry	Dublin	1	3	453[45]	169[46]	1240[47]	671[48]	1100	1792
Belfast	Dublin	2	3	1083[49]	544[50]	1240	671	1100	> 2000
Derry	Shannon	1	5	453	169	1240	671	718	1751
Belfast	Shannon	2	5	1083	544	1240	671	718	> 2000

[43] This study was performed with an intact 110kV network. NIE occasionally sectionalise the 110kV network which could affect the transfer capability
[44] presuming the Republic of Ireland system is reinforced with a Corduff Louth 220kV circuit
[45] overload Coolkeeragh Strabane 110 165 MVA for loss of Coolkeeragh Strabane 110 ckt 2
[46] overload Coolkeeragh Strabane 110 165 MVA for loss of Coolkeeragh Magherafelt 275kV double circuit
[47] overload Louth 275/220 600 MVA for loss of Louth Tandragee 275kV ckt 2
[48] overload new Louth 275/220 600 MVA for loss of Louth Tandragee 275kV double circuit
[49] overload Hannahstown IBT1 240 MVA (+10%) for loss of Hannahstown IBT2
[50] overload Dungannon Tyrone 110 165 MVA for loss of Tandragee – Tyrone (Magherafelt) 275kV double circuit

Arva Tyrone 275kV

Power to Republic of Ireland

2006/07 Winter - 275kV Option A+						Arva Tyrone 275			
Transfer				NI System[51]		Interconnections		RoI System[52]	
From	To	Ref		N-1	N-DC	N-1	N-DC	N-1	N-DC
Derry	Dublin	1	3	485[53]	174[54]	987[55]	707[56]	1204[57]	1114[58]
Belfast	Dublin	2	3	1120[59]	864[60]	972	727	1199	1116
Derry	Shannon	1	5	486	174	1059	707	874	1099
Belfast	Shannon	2	5	1127	867	1042	717	872	1104

51 This study was performed with an intact 110kV network. NIE occasionally sectionalise the 110kV network which could affect the transfer capability

52 presuming the Republic of Ireland system is reinforced with a Corduff Louth 220kV circuit

53 overload Coolkeeragh Strabane 110 166 MVA for loss of Coolkeeragh Strabane 110 ckt 2

54 overload Coolkeeragh Strabane 110 166 MVA for loss of Coolkeeragh Magherafelt 275kV double circuit

55 overload Louth 275/220 600 MVA for loss of Louth Tandragee 275kV ckt 2

56 overload Strabane PST 125 MVA for loss of Louth Tandragee 275kV double circuit

57 overload Drybridge Louth 110 125 MVA for loss of Gorman T2102 (with Corduff Louth 220)

58 overload Arva Louth 220 518 MVA for loss of Louth Tandragee 275kV double circuit

59 overload Hannahstown 275 / 110 240 MVA (+10%) for loss of Hannahstown IBT2

60 overload Ballylumford Kells 275kV 820 MVA for loss of Hannahstown – Moyle (Ballylumford) 275kV double circuit

Coolkeeragh Srananagh 275kV

Power to Republic of Ireland

2006/07 Winter - 275kV Option B+						Coolkeeragh Srananagh 275			
Transfer				NI System[61]		Interconnections		RoI System[62]	
From	To	Ref		N-1	N-DC	N-1	N-DC	N-1	N-DC
Derry	Dublin	1	3	621[63]	430[64]	959[65]	810[66]	836[67]	843[68]
Belfast	Dublin	2	3	1170[69]	876[70]	889	788	1140[71]	803[72]
Derry	Shannon	1	5	646	456[73]	1032	786	698	868[74]
Belfast	Shannon	2	5	1110	883	952	835	899	867

It is clear, when compared with Arva Tyrone 275, that the Coolkeeragh Srananagh 275kV circuit is good for getting power out of Coolkeeragh. Conversely, Arva Tyrone gives superior power transfer from Dublin to Belfast. Thus, Arva Tyrone 275 gives an increase in power transfer capability in both directions, whereas Coolkeeragh Srananagh 275 increases power transfer in one direction primarily.

[61] This study was performed with an intact 110kV network. NIE occasionally sectionalise the 110kV network which could affect the transfer capability
[62] presuming the Republic of Ireland system is reinforced with a Corduff Louth 220kV circuit
[63] overload Omagh Strabane 110 103 MVA for loss of Omagh Strabane 110 ckt 2
[64] overload Omagh Strabane 110 103 MVA for loss of Coolkeeragh Magherafelt 275kV double circuit
[65] overload Louth 275/220 600 MVA for loss of Louth Tandragee 275kV ckt 2
[66] overload Srananagh 275/220 600 MVA for loss of Louth Tandragee 275kV double circuit
[67] overload Srananagh T2101 220 / 110 125 MVA (+10%) for loss of Srananagh T2102
[68] overload Corraclassy Gortawee 110 126 MVA for loss of Louth Tandragee 275kV double circuit
[69] overload Kells 275 / 110 240 MVA for loss of Kells IBT2
[70] overload Ballylumford Kells 275 for loss of Hannahstown Ballylumford/Moyle 275kV double circuit
[71] overload Srananagh T2101 220 / 110 125 MVA (+10%) for loss of Srananagh T2102
[72] overload Corraclassy Gortawee 110 126 MVA for loss of Louth Tandragee 275kV double circuit
[73] overload Omagh Strabane 110 103 MVA for loss of Coolkeeragh Magherafelt 275kV double circuit
[74] overload Flagford Lanesboro 110 126 MVA for loss of Louth Tandragee 275kV double circuit

2006/7 Results - Power to Northern Ireland

The transfer capabilities calculated for power transfer to Northern Ireland for 2006/7 winter are as follows.

Existing

2006 / 7 Winter - Basecase+						No New Interconnectors			
Transfer				NI System[75]		Interconnections		RoI System[76]	
From	To	Ref		N-1	N-DC	N-1	N-DC	N-1	N-DC
Dublin	Derry	3	1	518[77]	283[78]	638[79]	295[80]	737[81]	295[82]
Dublin	Belfast	3	2	1970[83]	295[84]	638	295	737	295
Shannon	Derry	5	1	518	283	638	295	288[85]	295
Cashla	Belfast	6	2	1970	295	638	295	775[86]	295

The system separation limit for power transfer to Northern Ireland is 295 MW.

Shaded boxes:- The presence of a remedial action scheme whereby on loss of the Louth Tandragee, the systems separate tends to protect both the other interconnector circuits and the circuits in the Republic of Ireland from the transmission implications of the loss of Louth Tandragee 275kV double circuit. The impact of system separation on restricting power transfers is discussed in section 6.

75 This study was performed with an intact 110kV network. NIE occasionally sectionalise the 110kV network which could affect the transfer capability

76 presuming the Republic of Ireland system is reinforced with a Corduff Louth 220kV circuit

77 loss of Coolkeeragh 240 MVA transformer overloads other Coolkeeragh 240 MVA transformer

78 loss of Coolkeeragh Magherafelt double circuit overloads proposed Drumkee / Tyrone 120 MVA transformer with some overload allowed

79 overload Louth 600 MVA 275 / 110kV transformer for loss of other Louth Tandragee circuit

80 Without system separation would overload Corraclassy Enniskillen 110 for loss of Louth Tandragee 275kV double circuit

81 includes an additional Louth Corduff 220kV circuit

82 Without system separation would overload Arva Gortawee 110 for loss of Louth Tandragee 275kV double circuit

83 overload Lisburn Tandragee 110 for loss of Castlereagh Tandragee 275

84 Without system separation would overload Enniskillen Omagh 110 for loss of Louth Tandragee 275kV double circuit

85 overload Cashla Ennis 110 for loss of Cashla Prospect 220

86 overload Cashla Cloon 110 165 MVA for loss of Cashla Flagford 220

Louth Tandragee 275kV 3rd circuit

Power to Northern Ireland

2006/07 Winter - 275kV Option C+						Louth Tandragee circuit 3			
Transfer				NI System[87]		Interconnections		RoI System[88]	
From	To	Ref		N-1	N-DC	N-1	N-DC	N-1	N-DC
Dublin	Derry	3	1	334[89]	271[90]	1204	633[91]	767[92]	1099[93]
Dublin	Belfast	3	2	1968	1558	1204	633	767	>2000
Shannon	Derry	5	1	558	271	1204	633	255[94]	1099
Cashla	Belfast	6	2	1968	1558	1204	633	737	>2000

A Louth Tandragee 275kV reinforcement was also considered as an interconnector option. The disadvantage of Louth Tandragee is that a residual risk of system separation would remain. The residual risk is that a single incident at either Louth or Tandragee would result in system separation. This is a weakness that is not shared with the other interconnector options. The performance of this option, as presented in the table above, is only relevant if doubts as to the residual risk of a system separation are overcome. That issue will be addressed in the phase 2 report.

87 This study was performed with an intact 110kV network. NIE occasionally sectionalise the 110kV network which could affect the transfer capability

88 presuming the Republic of Ireland system is reinforced with a Corduff Louth 220kV circuit

89 overload Coolkeeragh 240 MVA transformer for loss of other transformer

90 overload Coleraine Kells 110 103 MVA for loss of Coolkeeragh Magherafelt 275kV double circuit

91 overload Louth 600 MVA 275 / 110kV transformer for loss of Louth Tandragee 275kV double circuit

92 overload Louth Woodland 220 520 MVA for loss of Gorman Maynooth 220 (presuming Corduff Louth 220 exists)

93 overload Cathaleen's Fall Letterkenny 110 126 MVA for loss of Coolkeeragh Magherafelt 275kV double circuit

94 overload Cashla Ennis 110 for loss of Cashla Prospect 220

Arva Tyrone 275kV

Power to Northern Ireland

2006 / 7 Winter - 275kV Option A +						Arva-Tyrone			
Transfer				NI System[95]		Interconnections		RoI System[96]	
From	To	Ref		N-1	N-DC	N-1	N-DC	N-1	N-DC
Dublin	Derry	3	1	513	285[97]	861[98]	753[99]	798[100]	730
Dublin	Belfast	3	2	1856	1535	848	756	797	721
Shannon	Derry	5	1	512	285	923	742	248[101]	897
Cashla	Belfast	6	2	1607	1382	948	737	691[102]	914

[95] This study was performed with an intact 110kV network. NIE occasionally sectionalise the 110kV network which could affect the transfer capability
[96] presuming the Republic of Ireland system is reinforced with a Corduff Louth 220kV circuit
[97] overload Coleraine Kells 110 103 MVA for loss of Coolkeeragh Magherafelt 275kV double circuit
[98] overload Louth 275/220 600 MVA for loss of Louth Tandragee 275 circuit
[99] overload Arva 275/220 600 MVA for loss of Louth Tandragee 275 double circuit
[100] overload Corduff Platin 110 126 MVA for loss of Gorman Maynooth 220. (presuming Corduff Louth 220 and ignoring overloads at lower transfers on Gorman Navan and Corduff T2101)
[101] overload Cashla Ennis 110 for loss of Cashla Prospect 220
[102] overload Flagford Lanesboro 110 for loss of Cashla Flagford 220

Coolkeeragh Srananagh 275kV

Power to Northern Ireland

2006 / 7 Winter - 275kV B +				Coolkeeragh-Srananagh					
Transfer				NI System[103]		Interconnections		RoI System[104]	
From	To	Ref		N-1	N-DC	N-1	N-DC	N-1	N-DC
Dublin	Derry	3	1	509[105]	367[106]	755[107]	648[108]	812[109]	372[110]
Dublin	Belfast	3	2	>2000	1407	699	601[111]	797	354
Shannon	Derry	5	1	498	393	812	698	257[112]	420[113]
Cashla	Belfast	6	2	>2000	1431	777	668	708	425

[103] This study was performed with an intact 110kV network. NIE occasionally sectionalise the 110kV network which could affect the transfer capability

[104] presuming the Republic of Ireland system is reinforced with a Corduff Louth 220kV circuit

[105] overload Coolkeeragh 275/110 240 MVA (+10%) transformer for loss of other transformer

[106] overload Coolkeeragh Kells 110 103 MVA for loss of Coolkeeragh Magherafelt 275kV double circuit

[107] overload Louth 275 / 220 600 MVA for loss of Louth Tandragee ckt 2

[108] overload Corraclassy Enniskillen 110 126 MVA for loss of Louth Tandragee 275kV double circuit

[109] overload Corduff Platin 110 126 MVA for loss of Gorman Maynooth 220 (with Corduff Louth 220)

[110] overload Arva Gortawee 110 126 MVA for loss of Louth Tandragee 275kV double circuit

[111] overload Corraclassy Enniskillen 110 126 MVA for loss of Louth Tandragee 275kV double circuit

[112] overload Cashla Ennis 110 126 MVA for loss of Cashla Prospect 220

[113] overload Arva Gortawee 110 126 MVA for loss of Louth Tandragee 275kV double circuit

Alternatives to Extracting Power from Coolkeeragh

An additional TLTG study is performed showing the impact of the interconnector development options in another direction; from Coolkeeragh to Belfast.

For comparison purposes the results for the proposed interconnections are compared with another reinforcement, an additional 275kV line from Coolkeeragh to Tyrone. This analysis presumed that this additional 275kV line is in addition to all existing lines. I.e. it is not treated as a replacement for an existing circuit.

2006/07 Winter				Derry to Belfast	
				NI System	
Reinforcement		Ref		N-1	N-DC
base		1	2	499[114]	171[115]
Arva	Tyrone	1	2	533	172
Coolkeeragh	Srananagh	1	2	592	384[116]
Coolkeeragh	Tyrone 275	1	2	636[117]	824[118]

Shaded boxes:- The presence of a remedial action scheme whereby on loss of Coolkeeragh Magherafelt 275kV double circuit, a fast run back signal is to be sent to generation at Coolkeeragh is considered by Northern Ireland electricity to address these problems for power transfers up to 400 MW.

There are two separate issues with getting power out of the Coolkeeragh area. The first problem is that the loss of one Coolkeeragh Strabane 275kV circuit overloads the other. The second problem is that the loss of the Coolkeeragh Magherafelt 275kV double circuit overloads the Omagh Strabane 110kV line.

It is found that although Coolkeeragh Srananagh 275kV is better than Arva Tyrone 275 for getting power out of the Coolkeeragh area, it does not compare with other 275kV reinforcements in this regard.

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[114] overload Coolkeeragh Strabane 110 166 MVA for loss of Coolkeeragh Strabane 110 ckt 2

[115] overload Omagh Strabane 110 103 MVA for loss of Coolkeeragh Magherafelt 275kV double circuit

[116] overload Omagh Strabane 110 103 MVA for loss of Coolkeeragh Magherafelt 275kV double circuit

[117] overload Coolkeeragh Strabane 110 165 MVA circuit 1 for loss of circuit 2

[118] overload Omagh Strabane 110 103 MVA for loss of Coolkeeragh Magherafelt 275kV double circuit

Appendix 2 – Small Signal Stability