Cer/05/258

Report on investigation into System Disturbance of August 5th 2005

NATIONAL GRID

11th December 2005

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Executive Summary

- At 10.22.22 hrs on Friday 5th August 2005 a power system incident led to the temporary loss of supply to 326,000 customers in Ireland and a further 74,000 customers in Northern Ireland

- The primary cause was the incorrect detection of a separation of the two power systems on the island (Ireland and Northern Ireland). The systems had not in fact separated. The cause of the incorrect operation is believed to have been radio interference.

- A secondary cause was the incorrect operation of the Moyle interconnector 'run-back' scheme, a scheme intended to maximise the permitted flow on the North – South Interconnector and to protect Northern Ireland's power system from the effects of excess output following separation. The scheme initially operated correctly in response to the command it received but subsequently operated incorrectly by changing the import on the Moyle interconnector twice, rather than once, thereby almost doubling the reduction of the presumed excess.

- A third contributor to the incident was the subsequent performance of three large ESB-owned generating units. Two generators ceased production completely and a third suffered a large reduction in output. This behaviour, precipitated by the initial disturbance, exacerbated the situation and further reduced the frequency.

- Automatic reconnection of customers commenced at 10.46 hrs and was complete by 12.00 hrs.

- The under-frequency load-shedding scheme and the automatic frequency restoration scheme performed as designed and protected the integrity of the power system.

- Following the event, the capacity of the North-South interconnector was temporarily reduced to protect the two power systems.

- The operation of the system separation detection scheme has since been modified to prevent a recurrence.

- The Moyle 'run-back' scheme has been modified by Moyle Interconnector Limited to rectify the design flaw so as to prevent a recurrence of the incorrect second reduction. Following this modification, the capacity of the North-South interconnector was restored on Tuesday 16th August.

- Investigation of the system separation scheme continues. ESB National Grid and SONI are considering design changes.

- ESB Power Generation has investigated the generators' performance, and some remedial actions have been taken.

- The likelihood of a recurrence of this event has been greatly reduced by the remedial measures described in the report.

Final Report on System Incident of August 5th 2005

Factual Information

- At 10.15 hrs on Friday 5th August, 2005, the power system was operating normally. [System conditions are recorded every 15 minutes. The position at 10.15 hrs was the recorded position closest to the incident.] The system demand was 3,302 MW, 377MW of which was being served by an import from Northern Ireland. Total output from wind generators was 81 MW. The power system frequency was normal at 49.973 Hz. Operating reserves were normal and generating plant availability was more than sufficient at 4,880 MW. See table 1 for the detailed system conditions at 10.15 hrs. See also Appendix 8 for a note on operating reserve policy.

- The transmission system conditions before the incident were as follows: Several circuits were out of service for maintenance (This is normal at this time of year when the electricity demand is relatively low and most maintenance is carried out during the summer months). A full list of transmission outages is contained in Appendix 7. The most significant outage on this day was the Louth – Tandragee No. 1 275 kV line, one half of the double-circuit interconnector to Northern Ireland. This line was out of service to permit maintenance at Louth 220 kV station, one of the terminals of the interconnector. Appendix 9 is a copy of the Voluntary Outage Memorandum covering this outage.

- At 10:22:22 on Friday August 5th an inter-trip signal was detected in Tandragee (a transmission station in Northern Ireland) on the Louth No. 1 275kV circuit, which was out of service for maintenance. The detection of this signal, which indicated that the North-South 275kV interconnector had tripped, caused another signal to be sent to Ballycronan More instructing the Moyle DC interconnection to Scotland to run-back. The North-South 275kV interconnector was in service and had not tripped. An inter-trip signal had not been transmitted from Louth. The run-back on the Moyle operated correctly as instructed and reversed an import of 115 MW to 168 MW export. The power system frequency dropped to 49.52 Hz. It then recovered to 49.83 Hz. The normal value is 50.00 Hz.

- The signal indicating incorrectly that the North-South 275 kV interconnector had tripped was also relayed to Enniskillen and Strabane leading to the tripping of the two standby 110 kV interconnectors. This had no significant effect as the two power systems remained interconnected through the Louth-Tandragee No. 2 275 kV line.

- At 10:24:21 a second run-back occurred on the Moyle Interconnector. It increased the export to Scotland from 168 MW to 416 MW and caused the power system frequency to drop to 48.82 Hz. Both interruptible and normal tariff customers were automatically

disconnected. The second run-back was triggered by a two-minute timer in Ballycronan More, which, when it timed out, saw that the original inter-trip signal in Tandragee was still latched on and assumed the 275kV interconnector had tripped.

- At 10:25:29 Tarbert unit 4, while responding to the low frequency caused by the second run-back on the Moyle, started to drop load due to control problems. This unit tripped at 10:27:06.

- At 10:26:43 Moneypoint unit 1 also started to experience problems while responding to the low frequency caused by the second run-back on the Moyle. It tripped at 10:27:46.

- The frequency nadir of 48.41 Hz occurred at 10:27:48 after Moneypoint unit 1 had tripped. An estimated total of 500 MW (system demand had dropped from 3311 to 2817 MW) or 15.6% of system demand (over 300,000 customers) had been disconnected at this point in Ireland. SONI had shed 144 MW or 11.4% of the Northern Ireland system demand.

- At 10:29:41 SONI reduced the export to Scotland from 416 MW to 250 MW by blocking the operation of 50% of the Moyle interconnector. This raised the power system frequency to 48.8 Hz, and assisted the recovery.

- Moneypoint unit 2 then started to drop load to 82 MW from 297 MW but due to load shedding and the response of other generators the effect on the frequency was masked. The unit did not trip.

- 95% of the disconnected customers were reconnected by 11:30 while all customers were reconnected by 12:00.

- SONI restricted the North –South Net Transfer Capacity (NTC) as a result of the fault. It returned to normal at 0600 on Tuesday August 16th.

- On August 6th both Tarbert unit 4 and Moneypoint unit 1 tripped again causing an amber alert to be issued. Detailed timings of the incident are outlined in Appendix 1. Charts for the interconnector flow and system frequency are included in Appendix 2.

Comment on Fault and Remedial Actions

Causes of load shedding

The loss of load was due to the initiation by a spurious command from the North – South Interconnector Special Protecion Scheme of the run-back facility on the Moyle interconnector, its subsequent incorrect second run-back, the loss of Tarbert unit 4 and Moneypoint unit 1, and the reduction in output from Moneypoint unit 2. The amount of load shedding which would have occurred had these three generators performed as expected would have been much less and might have been avoided, despite the net loss to the island of 531 MW. Had the second run-back of the Moyle interconnector not occurred, load shedding might also have been avoided – the second shock to generators still struggling after the first disturbance appears to have triggered the loss of output from these machines.

Moyle Direct Current Interconnector

Description of System Separation Detection Scheme and Moyle Run-Back Scheme

Two schemes are in place which are relevant to the event of 5th August. These are described below, and their performance is analysed and discussed.

System Separation Detection Scheme

The two electrical power systems on the island are interconnected by the Louth-Tandragee 275 kV interconnector and by two smaller 110 kV interconnectors between Letterkenny and Strabane and between Corraclassy and Enniskillen. The two 110 kV interconnectors are not capable of handling the flows carried by the larger 275 kV interconnector, so a scheme to detect loss of 275 kV interconnection is in place. This scheme is designed to trip the 110 kV interconnectors on loss of the 275 kV interconnector.

With the advent of the Moyle direct current link between Northern Ireland and Scotland, this system separation detection scheme was extended to command a change in the flow on the Moyle following loss of interconnection.

The scheme has components in both Louth and Tandragee. If the Louth element detects loss of interconnection it sends trip signals to Letterkenny and Corraclassy. It also transmits the loss of interconnection signal to Tandragee. If the Tandragee element detects loss of interconnection it sends trip signals to Strabane and Enniskillen and sends a “run-back” command to the Moyle interconnector. It also sends a “run-back” command to Moyle if it receives a loss of interconnection signal from Louth.

The signalling between Louth and Tandragee is carried on a Power Line Carrier system, a standard telecommunications medium on power systems. In normal operation a pilot frequency signal is transmitted continuously. When it is required to send a command from one terminal to

the other, the pilot frequency signal is removed and a guard frequency is transmitted. Following this, the guard frequency is replaced by a trip frequency. In other words, to operate the output relays, the absence of a pilot frequency and the presence of a trip frequency are required.

On the occasion of this event, the Louth-Tandragee 1 PLC link was operating with a severely attenuated pilot signal as a result of the application of earths to the line for safety reasons during the maintenance outage. Thus, one condition for the receipt of a trip signal was already present. It appears that an unidentified external source transmitted briefly at or near the trip frequency, resulting in a loss of interconnection signal being received at Tandragee, even though none was transmitted from Louth – this was confirmed by the automatic equipment logs at both Louth and Tandragee.

The Moyle Run-Back Scheme

System Operator Northern Ireland (SONI) uses the loss of interconnection signal to initiate the run-back facility in the Moyle controls to alter the flow on the Moyle interconnector in order to protect the Northern Ireland power system from excess power resulting from loss of interconnection while exporting to Ireland. The scheme is designed to maximise the capacity made available for market flows on the North – South Interconnector and allows SONI to choose the change in flow appropriate to the export. In the event of loss of interconnection the programmed change in flow occurs automatically. On this occasion the flow was reversed, turning an import of 115 MW into an export of 168 MW. This action would have been correct had North – South interconnection been lost.

Because of a design flaw in the run-back scheme, a second run-back command was issued two minutes after the first one. This increased the export to Scotland to 416 MW, causing a deficit on the island of 531 MW.

Remedial actions

Moyle has altered the run-back scheme that transmits run-back signals to the control system for the Moyle interconnector so that a second run-back signal can no longer be issued while the inter-trip signal is latched on in Tandragee. The two minute timer can now only start after the signal is reset in Tandragee.

A meeting with SONI, Siemens, Moyle Interconnector Limited (MIL) and UK National Grid to discuss the operation of the Moyle in greater detail took place on August 25th. MIL and ESBNG have requested that SONI investigate if a second signal, such as frequency or an alternative, can be used to verify the inter-trip signal before the run-back signal is issued to the Moyle interconnector.

ESBNG, MIL and SONI are also considering other options which may be implemented in order to improve the control of Moyle. A run-back analogue value scheme relating to actual north-south flow is to be designed. This is being considered by MIL.

The inter-trip signal latch is to be moved from Tandragee to Ballycronan More, the terminal station of the Moyle interconnector in NI, and manual intervention will be required to reset at Bally Cronan More. This action rests with NIE.

ESB National Grid and SONI will examine other possibilities for signalling between Louth and Tandragee to determine if a more secure communications system is appropriate.

Present Status

Operational procedures during line outages will remove the possibility of false signalling from Louth during line outages. Further modification work is in progress to minimise the risk of unnecessary 'false' runbacks. The present status of the Moyle controls and run back signalling equipment will ensure only one run back occurs if requested.

Performance of under-frequency load-shedding scheme

In order to protect power systems from total collapse in the event of a severe disturbance resulting in an imbalance between demand and production, underfrequency load-shedding schemes are necessary. The frequency of the electrical system is normally 50 Hz. A sudden loss of production or a sudden increase in demand will cause the system to slow down – this is manifested in the frequency falling. Small variations are dealt with by the automatic action of generators. Large variations arising from large imbalances trigger the safety net - the underfrequency load-shedding scheme. Demand is disconnected from the system automatically and progressively so as to restore the balance and therefore the frequency.

The underfrequency load-shedding scheme has been in use for more than 30 years and is well tried and understood. The specific underfrequency settings are under continual review and are adjusted in response to changing system conditions. Factors which are taken into account include the size of the largest generating units connected to the systems on the island, the growth in the size of the systems, and the fair treatment of all customers.

The Irish power system has both an automatic underfrequency load-shedding scheme and an automatic frequency restoration scheme which reconnects customers as soon as the frequency recovers.

ESB Networks reported to ESB National Grid on the performance of the underfrequency load-shedding scheme. The relevant sections of this report are included as Appendix 4.

Design operation of the underfrequency load-shedding scheme on this occasion should have involved tripping of total of 82 feeders, however some incorrect operation occurred as 10 feeders failed to trip as expected. In addition 5 feeders tripped when they should have remained in service. Analysis of the performance indicates that most of the failures to operate occurred because of the inherent tolerances in the settings.

ESBNG has been in the process of altering the settings of the under frequency relays. This was in progress at the time of the incident. The effect of these changes is to disconnect customers at higher frequency (48.85-45.50 Hz) thus arresting the frequency fall at a higher level. This process is ongoing. It is coordinated with SONI to ensure the alterations to the settings of the underfrequency relays are completed.

In summary, the performance of the underfrequency load-shedding was good. The failure-to-trip incidents were balanced by additional unexpected trippings resulting in a loss of load comparable with the system design. The scheme operated correctly and prevented power system collapse.

Generator Performance

General

When a power system event occurs which causes a low frequency due to an imbalance between production and demand, the running generators are expected to automatically increase their output, providing what is known as operating reserve.

At the time of the incident on 5th August, there were 20 generators (comprising 15 generating units, as some units such as combined-cycle units have more than one generator) connected to the system and producing. Of the 20 generators, most performed as expected. However, as already mentioned, the severity of the incident was exacerbated by the performance of three generating units, namely: Moneypoint Unit1, Tarbert Unit 4, and Moneypoint Unit 2. In this report we concentrate on the non-performing units.

ESB Power Generation has investigated the behaviour of the affected generators. The Draft report provided by ESB Power Generation is included as Appendix 3.

Moneypoint Unit 1

Moneypoint Unit 1, a 305 MW coal-burning unit (which can also burn oil) was operating at 308 MW before the event. (Operation at a nominal output of 305 MW can lead to actual outputs which vary around the target ouput by a few MW in response to system frequency variations). In response to the initial disturbance, caused by the first run-back on the Moyle interconnector, the output rose automatically rose to 316 MW, and then declined to 312 MW, still a net increase. Thereafter a sequence of events led to the complete loss of output by 10.27.46 hrs. The causes of this loss were fouled airheaters and the failure of a damper to operate correctly.

As reported by ESB Power Generation, the fouled condition of the airheaters was known and was to be addressed during a maintenance outage of the unit, scheduled to take place later in August.

Remedial actions have been proposed by ESB Power Generation. These are described in the attached report in Appendix 3. They include setting a limit of 305 MW on the output, in order to reduce the disturbing effect on the unit of a large frequency fall, modifying the control system to better cope with disturbances, and a review of operating procedures and training.

Moneypoint Unit 2

Moneypoint Unit 2, also a 305 MW unit, identical to unit 1 above, was operating at 283 MW before the event. The initial response to the disturbance increased the output to 299 MW with a second increase to 305MW. Subsequent events caused a decline in output to 85MW by 10.31 hrs. Output recovered later.

ESB Power Generation also attributed this loss of output to fouled airheaters, a condition which was to be rectified in a maintenance outage, scheduled for later that day.

The same remedial actions have been proposed for this unit as for unit 1 above.

Tarbert Unit 4

Tarbert Unit 4 is a 256 MW oil-fired unit which was operating at 201 MW prior to the incident. This unit responded initially by increasing automatically to 212 MW, and then declined to 200 MW. Subsequent events led to complete loss of output by 10.27.06 hrs.

A combination of factors contributed to the loss including inappropriate choice of control mode, failure of a spray-water valve to open automatically, and some design parameters in the control system.

ESB Power Generation has sought modifications to the control system from the manufacturers, and expects that these will be implemented before the return to service of the unit at the end of October. They also intend to perform testing of the spray-water valve after the return to service.

[This unit returned to service but suffered a fault the next day at 10.54 hrs on Saturday 6th August. It has remained out of service since then while major repairs are being carried out. It is expected to return to service before the end of October, when the remedial actions will have been completed.]

Conclusions

The power system was being operated normally prior to the incident.

The primary cause was the incorrect detection of a separation of the two power systems on the island (Ireland and Northern Ireland). The cause of the incorrect operation was radio interference from an unidentified source.

A secondary cause was the incorrect operation of the Moyle interconnector 'run-back' scheme, a scheme intended maximise the capacity available to the market on the North – South Interconnector and to protect Northern Ireland's power system from the effects of excess output following separation. The scheme initially operated correctly in response to the command it received but subsequently operating incorrectly by changing the import on the Moyle interconnector a second time, rather than only once, thereby doubling the reduction of the presumed excess.

A third contributor to the incident was the subsequent performance of three large ESB-owned generating units. Two generators ceased production completely and a third suffered a large reduction in output. This behaviour, precipitated by the initial disturbance, worsened the situation.

The underfrequency load-shedding scheme and the automatic frequency restoration scheme worked as intended and prevented power system collapse.

The causes have been identified. Remedies have been identified. All are being or have been implemented.

A recurrence is highly unlikely.

Recommendations

Primary Cause.
The primary cause was the incorrect detection of a separation of the two power systems on the island (Ireland and Northern Ireland). The cause of the incorrect operation is believed to have been radio interference.

Recommendation
Block the outputs from the Power Line Carrier on the out-of service interconnector circuit so as to prevent action being taken on receipt of a spurious system separation signal.

Status
Implemented by 12th August 2005

Recommendation
Investigate the possibility of using a different communications medium with coded messaging so as to improve the immunity to interfering signals.

Status
Ongoing. The replacement of Power line Carrier by another medium would be a long-term project.

Secondary Cause
A secondary cause was the incorrect operation of the Moyle interconnector 'run-back' scheme, a scheme intended to protect Northern Ireland's power system from the effects of excess output following separation. The scheme operated incorrectly by changing the import on the Moyle interconnector twice, rather than once, thereby doubling the reduction of the presumed excess.

Recommendation
Modify the Moyle Interconnector Run-Back scheme so as to prevent repeated run-back commands.

Status
Implemented by 12th August 2005

Contributory Factor
A third contributor to the incident was the subsequent performance of three large ESB-owned generating units. Two generators ceased production completely and a third suffered a large reduction in output. This behaviour, precipitated by the initial disturbance, exacerbated the situation.

Recommendation
Detailed recommendations are contained in the ESB Power Generation Report (Appendix 3). These include review and modification of control systems, testing of certain components, the setting down of turbine load limiters, the fitting of new controllers and a review of some operating procedures and training requirements.

Status
Several implemented, some underway, some awaiting the return to service of the affected generating unit.

Table 1 – Conditions at 10.15 hrs on 5th August 2005

Unit	MW	Unit	MW	Unit	MW	Unit	MW	Unit	MW	Unit	MW	Unit	MW
		GI1		**AD1**	261	AP5		BK1		AA1		**TH1**	41
		GI2		AT1		AT1		BK2		**AA2**	12	**TH2**	5
		GI3		AT2		AT2		ED1		AA3		TH3	
		TB1		AT4		AT4		FB1		AA4		**TH4**	44
		TB2		**MRC**	100	**MRC**		FB2		CL1			
		TB3						FB3		ER1			
		TB4	192					FB4		ER2			
MP1	291	MP1						LA2		ER3			
MP2	284	MP2		NWC		NWC		LA3		ER4			
MP3	259	MP3		NW5		NW5		RH1		LE1			
		PB1		PB1		AT5		RH2		LE2			
		PB2		PB2		AT6		RH3		LE3			
		PB3		PB3		AT7		SH1		LI1			
				PB4	124	**PB4**		SH2		LI2			
				PB5	124	**PB5**		SH3		LI4			
				PB6	149	PB6		WEC		LI5			
				DB1	398			**LR4**	81				
				HNC	333	TP1		**WO4**	146				
				SK3		TA1							
				SK4		TA2							
				TYC		TA3							
						TA4							
						RP1							
						RP2							
Coal	834	Oil	192	Gas	1489	Dist		Native	227	Hydro	12	TH	90

Sys Gen (Calc)	2925	T. Hill Level (Mtrs)	690.7407	PSR	
Sys Dmd (Calc)	3302	Gas Cork (MCF)		SSR	
A.C.E. (MW)		Gas Dublin (MCF)			
N.I.E. (MW)	-377	GSY		TH Gen	90
Time Err (Secs)	-5.008	Temperature	15	TH Pump	
Sys Mvar (Mvar)	466	Light Int.	763		
Availability (MW)	4880	Freq (Hz)	49.973	Wind Est (MW)	81

Appendix 1 - Incident Report

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Time	Event	Freq	SYD
10:22:00	ESB Importing 380 MW on 275 kV interconnector TB4=192MW, MP1=291MW, MP2=283MW, MP3=249MW	49.97	3311
10:22:22	PLC inter-trip signal received in Tandragee indicating that the 275kV interconnector was out of service. It was not out of service – the Louth-Tandragee 1 275kV line was, in fact, out of service for maintenance while the second line was in service. The inter-trip signal latched. First Moyle run-back from 115MW import to 168 MW export – An incremental change of **283 MW –** Both 110kV interconnectors tripped (in Enniskillen and Strabane)	49.65	3308
10:22:25	ESB/NIE Interconnector import drops to 215MW	49.52	3226
10:23:00	ESB/NIE Interconnector import drops to 171MW	49.79	3335
10:24:00	ESB/NIE Interconnector import 181MW TB4=202MW, MP1=305MW, MP2=299MW, MP3=249MW	49.83	3319
10:24:21	Two minute timer in Ballycronan More (with inter-trip signal still latched in Tandragee) causes second Moyle run-back from 168MW export to 416 MW export. An incremental change of **248 MW** – A total change of **531 MW**	49.59	3322
10:24:25	***Interruptible loads disconnected at 49.3 Hz (43MW)***	**49.25**	3219
10:24:33	***First normal tariff load shedding***	48.88	3220
10:24:40	ESB/NIE Interconnector = 45MW (export)	48.82	3153
10:25:00	ESB/NIE Interconnector = 59MW (export)	48.82	3155
10:25:29	Interconnector = 55MW (export) TB4=**161**MW, MP1=314MW, MP2=299MW, MP3=261MW	48.67	3127
10:25:35	ESB/NIE Interconnector = 81MW (export)	48.65	3084
10:25:50	ESB/NIE Interconnector = 88MW (export) *275kV Interconnector flow has changed from 380 MW import to 88 MW export* ***– A total change of 468 MW on 275kV interconnector***	48.73	3056
10:26:43	MP1 Wind Down Alarm	48.61	2984
10:26:44	Interconnector = 55MW (export) TB4=50MW, MP1=302MW, MP2=296MW, MP3=257MW	48.60	2984
10:27:06	Tarbert U4 CB Opened	48.54	2914
10:27:11	Interconnector = 0MW TB4=0MW, MP1=**219**MW, MP2=297MW, MP3=252MW	48.51	2907
10:27:24	Interconnector = 0MW TB4=0MW, MP1=**159**MW, MP2=299MW, MP3=256MW	48.60	2877
10:27:38	Interconnector = 28MW(import) TB4=0MW, MP1=81MW, MP2=292MW, MP3=252MW	48.47	2872

	Further load shedding leading to a total of 500 MW or 15.6% of system demand (over 300,000 customers) disconnected		
10:27:46	Moneypoint U1 CB opened	48.43	2922
10:27:48	Interconnector = 28MW(import) TB4=0MW, MP1=**0**MW, MP2=297MW, MP3=241MW	**48.41**	2847
10:29:50	One pole of Moyle blocked by CHCC reducing export to 250 MW	48.8	2847

Appendix 1 - Incident Report
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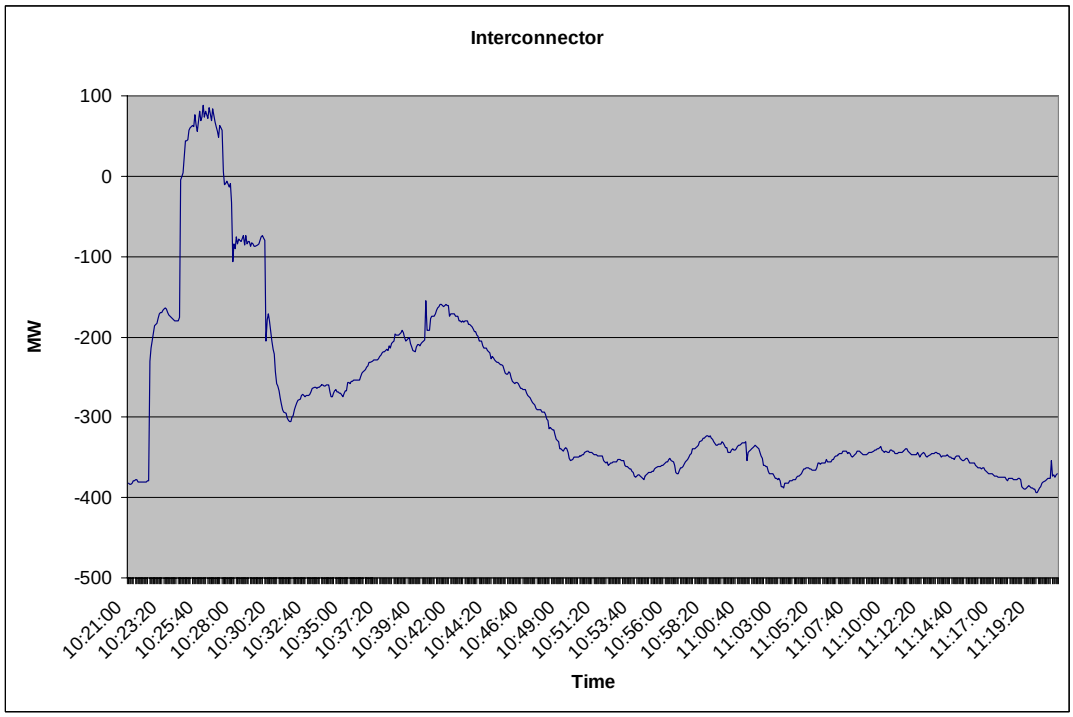
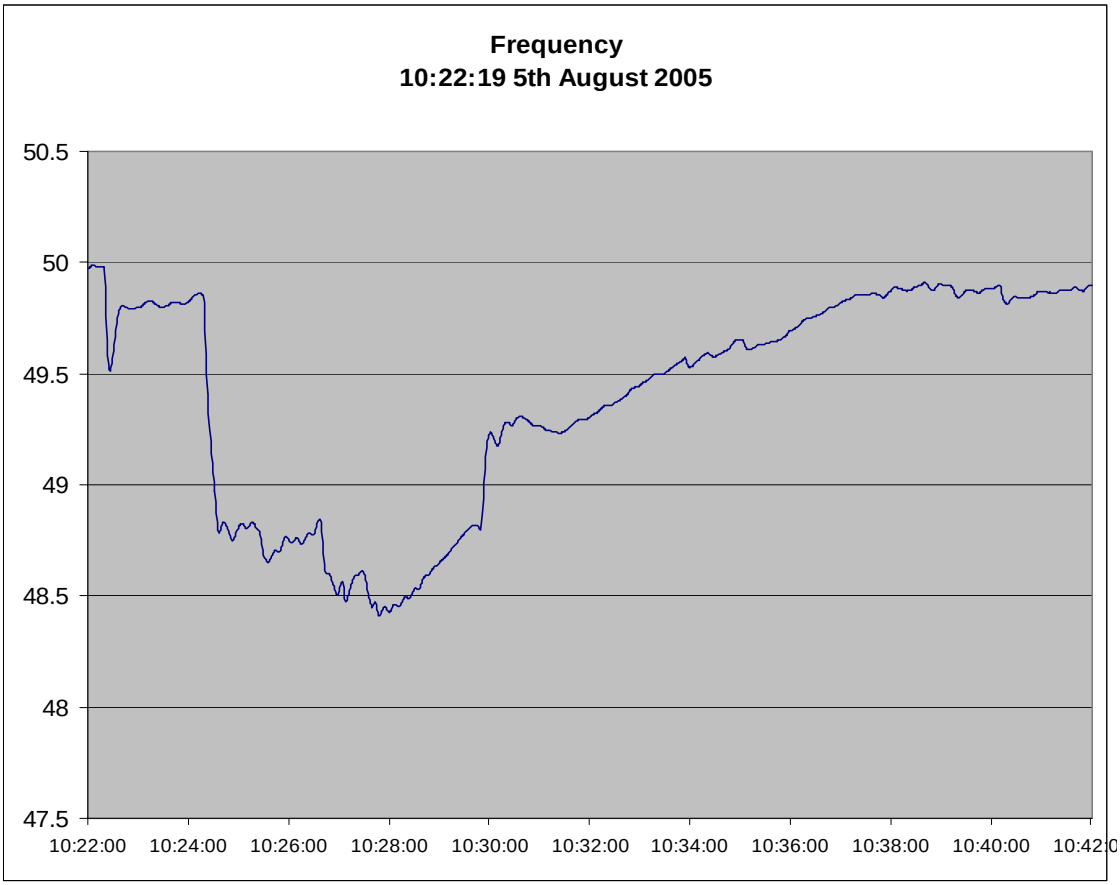
10:30:41	Interconnector = 264MW (import) MP2=**147**MW MP3=269MW	49.30	2861
10:31:30	Interconnector = 305MW(import) MP2=**82**MW	49.24	2817
10:35	Red Alert issued		2823
10:38:37		**49.90**	**2817**
11:30:00	95% of load reconnected		3256
12:00:00	Last customer reconnected		3311
12:07:00	Red Alert cancelled		3319
12:18	Inter-trip relay removed from service in Tandragee		3334
12:45	110kV interconnectors returned to service by CHCC		3352
12:53	Blocked pole returned to service on Moyle by CHCC		3337
	Saturday August 6th		
10:54	*TB4 tripped from 240 MW with a boiler tube leak*	49.68	
11:29	*Amber alert issued*		
13:00	*MP1 tripped from 300 MW*	49.67	

Appendix 2 - Incident Report

Friday 5th August 2005



Graph showing the flow on the north-south interconnector.



Graph showing the power system frequency

Appendix 3 – ESB Power Generation Draft Report

Draft Report on the response of ESB PowerGen Units Moneypoint 1, 2 and Tarbert 4 to frequency deviations on the 5th August 2005.

Summary

On the morning of the 5th of August 2005 at 10:22:19[1] the frequency dropped below 49.8 Hz to a nadir of 49.51 Hz at 10:22:24 before recovering to stabilise at 49.8.

A second incident occurred at 10:24:18 with a frequency nadir of 48.4 Hz at 10:27: 43. The frequency prior to the second incident (30 to 60 sec) was 49.81 Hz.

The initial response of the units to the second incident is shown below.

	Pre Incident Output	POR (5 to 15 secs.)	SOR (15 to 90 secs)
MP1	308	316	312
MP2	299	305	298
TB4	200	212	192

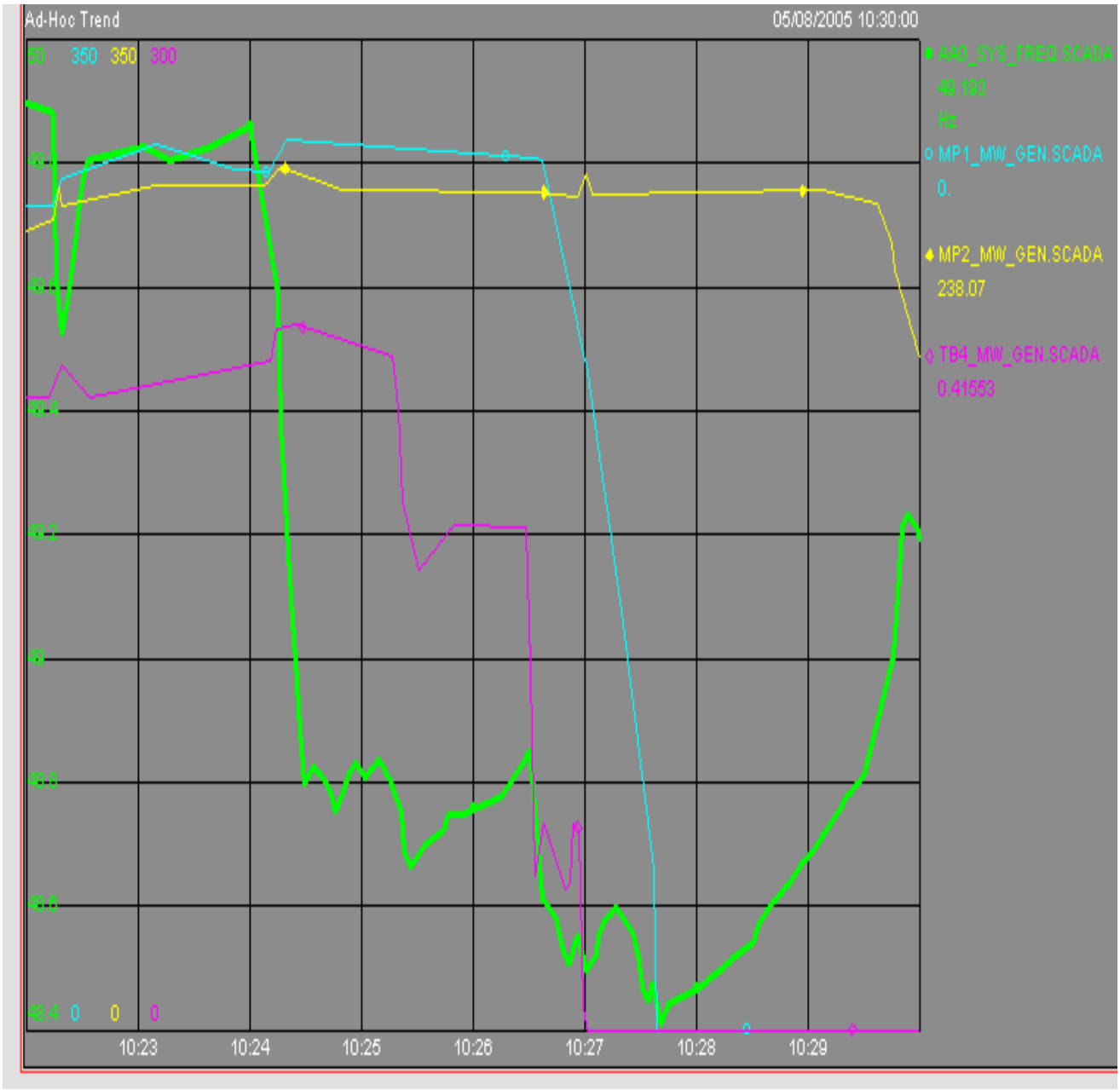
By 10:25:49 the load on Tarbert 4 had reduced to approximately 150 MW due to the action of the turbine pressure limiter. The boiler tripped on high inlet steam temperature to the reheater at 10:26:27 initiating a Fast Load Wind Down (FLWD) with the turbine tripping at 10:27:05.

In Moneypoint at 10:26:26 FD fan 1B tripped on high discharge pressure causing protection shut down of associated fans and mills in group. The remaining fans were unable to maintain adequate PA duct pressure causing a Master Fuel Trip at 10:26:42 which initiated a FLWD. Unit 1 generator was off the grid by 10:27:45.

FD fan 2A in Moneypoint tripped on high discharge pressure at 10:29:18 causing a protection shutdown of associated fans and mills in group and initiating a capability runback to a low of 83 MW before recovering to 155 MW.

[1] Times and loads are from EMC. There is no master clock for event recorders/ alarm system across ESB PowerGen Units.

Figure 1 Response of Units



Tarbert Unit 4

Prior to the first frequency deviation at 10:22:19 Unit 4 had been operating in Unit Co ordination Mode with Turbine Following Mode (UCMTFM). This is a modified sliding pressure (throttle valves 90% open) mode of operation where the turbine controls the boiler outlet pressure. This has been the normal mode of operation for this unit since commissioning the new C&I system.

In this mode the unit is capable of supplying coordinated response (increase in turbine load and boiler firing due to kxdf) of equivalent to 14.5MW on a frequency deviation. Beyond a 14.5MW deviation the turbine will try to increase load but the boiler firing will be limited to 14.5MW. The boiler will not increase firing to cope with deviations greater than approximately 0.12 Hertz.

On the morning of the 5th and prior to the first incident because of running at a lower system frequency than 50herz , 3MW of the possible 15 MW 'reserve of firing' was already used from the kxdf (frequency variation load demand) .

When the 1st frequency deviation of the morning occurred at approx. 10:22 the unit picked up load to 201MW, the load demand element due to frequency deviation kxdf ramped to its maximum value of 14.5 MW and the boiler firing increased appropriately. There is an initial pick up of load as the valves open to 100% and then as frequency restored somewhat the valves went back to 85%approximately before opening gradually to approx.90% with the load going back to its initial value and then rising again as valves open.

After approximately 90 seconds the system appears to be stabilising somewhere between 191 and 201 MW.

The kxdf signal remained at its maximum at 14.5MW, however, because of the remaining frequency deviation. When the second frequency deviation occurred at 10:24 turbine valves again then went 100% open and remained open because of the large demand from the frequency deviation. The boiler pressure then started to decay slowly because the boiler load did not correspond to actual load. The pressure set point started to ramp up. The live steam pressure set point was increasing and the live steam pressure was decaying. When the difference between them reached a preset value the Live Steam Pressure Limiter became active closing the throttle valves to under 60%. The boiler

pressure increased rapidly. When the difference between the boiler pressure and the boiler pressure set point came back to a preset value the live steam limiter switched off. The throttle valves remained at approximately 60% and the boiler pressure continued to rise. The HP bypass opened when the boiler pressure rose by the predetermined amount above the set point but the HP bypass spray water failed to open and boiler tripped on high reheat inlet temperature causing a FLWD.

ESB have met with ABB (suppliers of the C&I system) since this incident.

It is ABB's opinion that the preferred mode of operation for the unit is Unit Coordinated Mode Boiler Follow Mode (UCMBFM). UCBFM is already installed and commissioned. In UCMBFM the boiler pressure controller is active allowing the boiler to fire up on load demand deviations greater than 14.5 MW.

ESB have requested the following from ABB:

- Review of UCMBFM and the magnitude of kxdf going to boiler in light of the severe and prolonged frequency disturbance experienced on the 05/08/05
- Kxdf to be removed from UCMTFM to allow 'safe mode' of operation in the event of instability in the unit (To prevent cascade tripping on severe frequency dips)
- Automatic ramping of set points to be restricted if controlled variable not tracking. (To prevent unnecessary action of the Live Steam Limiter)

ABB have been requested to forward the expected time line for the completion of the above review/ modifications with proposals for appropriate testing.

ABB have been made aware of the urgency of the above work and the window of opportunity that exists until mid October to make changes off load.

ABB have undertaken to expedite this work and will forward proposals /programme by week 38.

It is not clear why the spray water control valve failed to open on the HP Bypass. The valve packing has been slackened off and the valve has operated satisfactorily on start up of the unit since the trip. Further investigation / testing of the spray water valve will be undertaken by Tarbert under the more onerous conditions that pertained to the incident of the 05/08/05 when the unit is returned to service.

Moneypoint

In Unit Co Ordinate Mode (UCM) the Moneypoint machines will respond to frequency deviations in the following manner. The turbine output will vary by the load demanded by the kxdf, the boiler will get a demand to vary firing by 50% of the kxdf and deviations

in boiler pressure will be catered for by the boiler pressure controller. The units are rated for 305 MW but due to the swallow capacity of the turbines and the excess capacity available in the steam generators the units are capable of a sustained 315MW output for a number of hours with higher calorific value coals *and a clean boiler*.

The span of the unit controls are from 0 to 330 MWS. If the kxdf is large enough the unit will attempt to go to 330MW and will be limited only by boiler firing capability or swallow capacity. With a 4% regulation a 0.1 Hertz frequency change will bring about a 16.5 MW load variation.

Unit 1

Unit 1 Moneypoint was operating in UCM on the 05/08/2005 generating 290MWs prior to the first incident.

The air heaters on the unit were fouled. Fouling occurs when the units have been on load for a number of months. It is necessary to clean the air heaters off load with specialist contractors. An outage for C&I work and airheater washing had been scheduled for the 23rd to the 28th of August

One of a number of effects of fouled air heaters is to increase the FD fan discharge pressure to alarm and eventually trip values as extra air for combustion is supplied on increasing load. This problem is well known to both the Station and the National Grid. As recently as the 4th of July FD fan 1B tripped on fan discharge pressure causing a capability runback.

When the first frequency incident occurred on the 05/08/05 the load on Unit 1 increased to a maximum of 312 MW and settled out at 308MW prior to the second incident. When the second incident occurred the load increased to a maximum of 318 MW before coming back to 312 MW. As the boiler attempted to meet the demand for steam the FD fan discharge pressure increased until it breached the trip limit on FD fan 1B 2 minutes and 9 seconds after the start of the second incident.

When FD fan 1B tripped its associated ID fan, PA fan and Mills A and C slave tripped. This was the correct operation of the interlocking system. The dampers associated with the tripped PA fan, however, did not close. This open path coupled with the lower air flow to the suction of the remaining PA fan because of blocked airheater baskets caused the primary air duct pressure to go below the trip value for the requisite time. The remaining in service mills tripped causing an MFT and FLWD.

Unit 2

Unit 2 also had fouled air heaters and was also on UCM generating 283MW prior to the first frequency incident. The boiler was operating at a reduced outlet pressure set point of 15.8 MPa because of difficulties with safety valves lifting light. The unit was due off for a scheduled outage that evening. An airheater wash was part of the work programme.

Following the first frequency excursion the load increased to and settled at 299MW.

When the second incident occurred, the load increased to 305 MW but the boiler was unable to sustain this load and it drifted down toward 298 MW. The FD fan discharge continued to increase as more combustion air was supplied to the boiler. Five minutes after the start of the second incident FD Fan 2A tripped on high discharge pressure. The associated ID, PA fan and Mills (A and C) slave tripped. The unit went to TFM and started a capability runback. The unit load went as low as 85MW possibly because the PA duct pressure went as low as 5 KPa from 8.9 KPa on the fan trips. The load recovered to 155MW aided by the duct pressure recovering to over 7KPa.

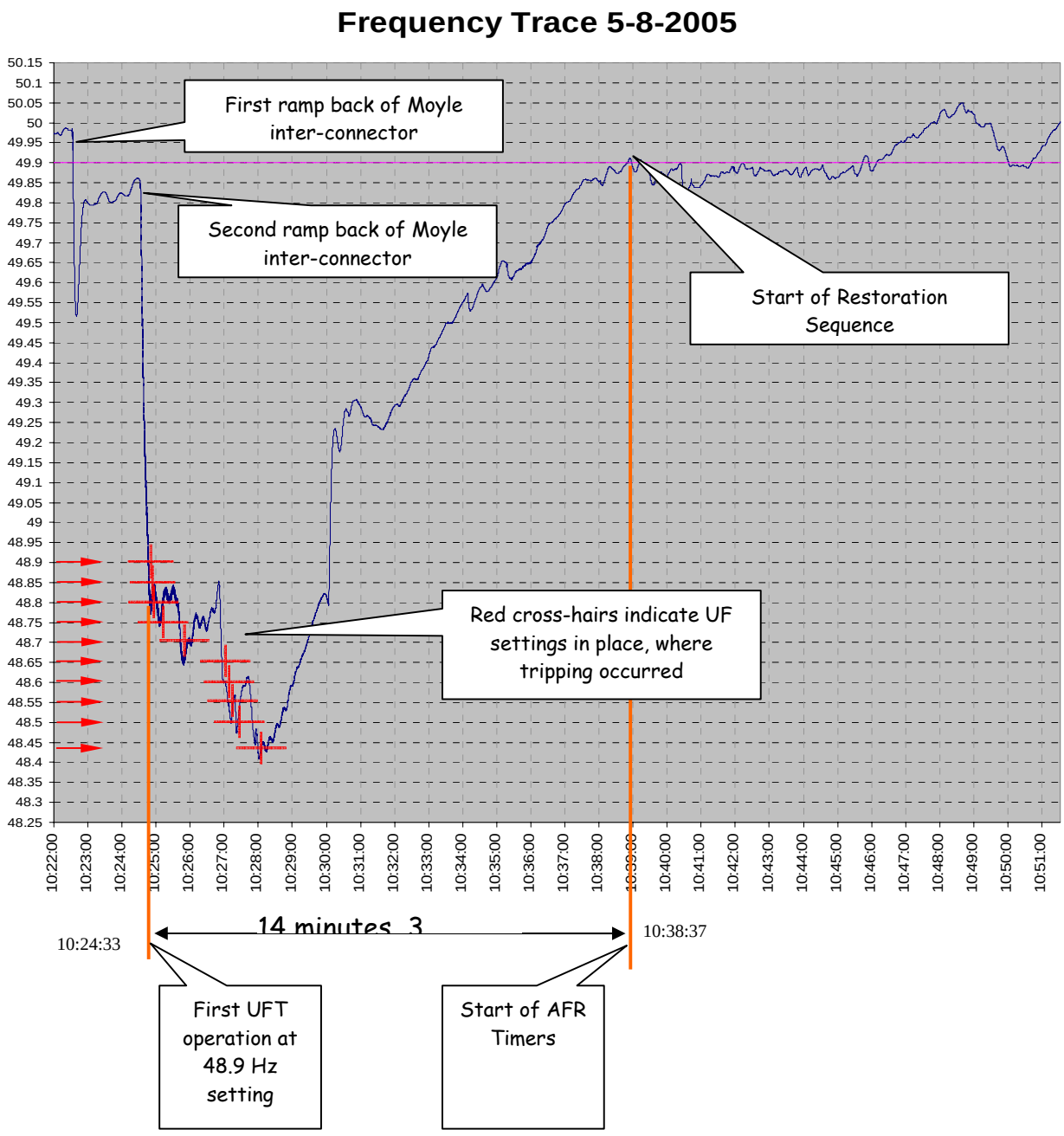
The operator reduced the unit load set point to 250MW at some indeterminate point after the start of the first incident in an attempt to reduce the FD fan discharge pressure and avoid tripping the unit.

In order to avoid a recurrence of the incidents in Moneypoint the following actions will be undertaken:

- The turbine load limiter will be set at 305MW. This will only be increased when there is a specific request to maximise from the Grid to the Shift Manager. The Shift Manager will assess the fitness of the unit to maximise before allowing the load limiter increase.
- The Manager, C&I Section, will investigate the design and implementation of a limiting controller on duct pressures.
- The station will review its standard operating procedures and training in relation to FD fan discharge pressures.

Appendix 4 – Extracts from report from ESB Networks on Underfrequency Load-shedding scheme performance

1. Profile of frequency event



Notes

- The recorded frequency nadir was 48.408. Hz
- Automatic Frequency Restoration [AFR] begins to time out at 49.9 Hz.

- The frequency first recovered to 49.9Hz after ~14 minutes. The automatic restoration sequence would have started shortly after that. However, because the frequency hovered around 49.9 Hz, the timing would have been paused and resumed several times. There is some uncertainty therefore about the exact predicted restoration times. In this report, for the purposes of analysis, predicted times have been calculated, based upon the assumption that the timing was not interrupted or paused. In any event, after some 24 minutes, the frequency rises and stays above 49.9 Hz. Therefore, it is clear that restoration should have taken place within 30 minutes.

2. Under-frequency [UF] settings in place

After the investigation into the 4-7-05 under-frequency event, the settings on the UF relays were confirmed and known. In the interim, a new tranche of settings were issued by National Grid and a programme for application of these settings, by ESBI, was underway. At the time of this incident this programme was in progress and the settings in 15 Stations had been changed. These are listed as follows:

Ardnacrusha
Binbane
Cahir
Butlerstown
Carlow
Doon
Ennis
Great Island
Kilkenny
Letterkenny
Limerick
Stratford
Tipperary
Trillick
Wexford

The analysis in this report, is based upon a master list, which includes the new settings where applied, and the pre-existing settings.

3. Feeders upon which UF tripping operated

Tripping is known to have occurred on 72 feeders. The full list is shown in appendix 1.

4. Feeders upon which UF tripping did not operate

110kV Station	Feeder	Voltage	Stations on outlet	Setting on 8-5-05
Finglas	Merville	38	Merville T42	48.600
Lanesboro	Aghamore	38	Aghamore	48.900
Limerick	Gillogue/Castletroy	38	Castletroy	48.500
Limerick	Patrickswell/Moneteen	38	Patrickswell	48.850
Lisdrum	Drumbear	38	Drumbear, Ballybay	48.425
MCDERMOTT	Clontarf	38	Clontarf	48.450
MCDERMOTT	Fairview	38	Fairview	48.450
Mullingar	Delvin	38	Delvin	48.900
Sligo	Manorhamilton	38	Manorhamilton	48.425
Tonroe	Charlestown	38	Charlestown	48.425

Table 1: Feeders failed to operate on UFT

5. UF protection performance

Proper design operation of UF protection on this occasion should have involved tripping of total of 82 feeders, however some incorrect operation

occurred as 10 feeders failed to trip as expected. The total numbers of station affected was 95.

In the case of Lisdrum, Sligo and Tonroe, these can be partially explained by tolerance or accuracy levels of the feeder relays: a sample of commissioning results shows that the typical tolerance range of FTG relays is 0.16 to 0.2 Hz. As this range is wider than adjacent UFT setting bands then it is inevitable that unselective tripping will occur. As the frequency nadir at 48.408) is well within the tolerance band of 48.425Hz it can be expected that many such relays would not have tripped.

In addition 5 feeders tripped when they should have remained in service. These are listed in appendix 1.

	Correct	Fail	Design Total	Additional incorrect
Number	72	10	82	5
Percentage	88%	12%	100%	

Table 2: Tripping performance summary

The UF protection performance was generally quite good. The failure-to-trip incidents were balanced by additional unexpected trippings resulting in a loss of load comparable with the system design.

The UF trippings instigated a series of automatic operations at the following locations:

Station	Auto Operation
Cratloe	ACO
Caherdavin	Auto OP
Moylish	ACL
Grange(Waterford)	ACO
Ballylinan Rd	ACO
Stradbally Rd	Auto OP
Tulla	ACO

Clarecastle	ACO
Ballyhale	ACO
Castlecomer	ACO
Southill	ACO
Kildare	ACO
Tramore	ACO
Derrybeg	ACO
Clones	ACO
Gort	ACO

Table 3: Automatic operations

In most cases the alternative supply was co-ordinated to trip also so the automatic did not result in the load being reconnected. However in the case of Gort, Cratloe, Clones and Derrybeg the load was reconnected following the ACO, making the UF action ineffective.
The setting and priorities in these situations should be reviewed to see if improvements can be implemented.

A similar case occurred at Grange (ex Butlerstown) but the ACO did not operate correctly due to a CB failure. The frequency priority on this feeder may need alteration as Grange supplies Waterford Regional hospital.

6. AFR performance

Sixty feeders restored automatically. Of these, 56 restored within the correct timeframe. Four restored too quickly.

A further 15 failed to restore automatically. Of these, 6 are feeders where no AFR is installed. The remaining 9 are unaccounted for at the time of writing.

	Correct	Too quick	Fail	Total
Number	58	4	15	77
Percentage	75%	5%	20%	100%

Full listings of these categories are given in Appendix 2.

Due to the automatic operations detailed above, many stations were restored via standby or alternative feeders. While this achieved effective restoration, the 38kV system consequently had many abnormal feeding situations. This in turn delayed DCCs's ability to assess and report on the restoration process. In one instance, Ballylinan Rd- Stradbally Rd, the automatic operations created a lock-out situation where the station did not restore even when the 38kV feeders had restored properly.

Appendix 1: Underfrequency Trippings :List of feeders and settings

Correct Trippings :

110kV Station	Feeder	kV	Stations on outlet	Setting on 8-5-05	Actual time down	Time Out	Time Restored
Ardnacrusha	Birdhill	38	Birdhill, Tyone	48.650	00:21	10:26	10:47
Ardnacrusha	Bruff	38	Bruff	48.850	00:50	10:27	11:18
Ardnacrusha	Cappamore	38	Cappamore	48.750	00:21	10:24	10:45
Ardnacrusha	Cratloe/Caherdavin	38	Cratloe	48.800	00:19	10:24	10:43
Ardnacrusha	Gillogue	38	Gillogue	48.500	00:21	10:27	10:49
Ardnacrusha	Moylish	38	Moylish, Caherdavin	48.800	02:27	10:24	12:51
Ardnacrusha	Southill	38	0	48.550	00:46	10:26	11:13
Ardnacrusha	Tulla	38	0	48.700	00:55	10:25	11:21
Arklow	Rathdrum/Kilmartin/ Wicklow	38	Kilmartin	48.900	00:25	10:24	10:49
Athlone	Ballygar	38	Ballygar, Glenamaddy	48.800	00:16	10:25	10:41
Athlone	Moate	38	Moate	48.800	00:21	10:25	10:46
BELLACORICK	Bangor Erris	38	Bangor Erris, Belmullet	48.800	01:06	10:24	11:30
Binbane	Glenties	38	Glenties, Dungloe, Clady, Derrybeg	48.500	00:21	10:27	10:48

110kV Station	Feeder	kV	Stations on outlet	Setting on 8-5-05	Actual time down	Time Out	Time Restored
BLACKROCK	Ballinaclea T41	38	Ballinaclea T41	48.700	00:16	10:25	10:41
BLACKROCK	Sallynoggin T41/T42	38	Sallynoggin T41/T42	48.800	00:15	10:24	10:39
Butlerstown	Grange	38	Grange	48.500	00:58	10:27	11:26
Butlerstown	Portlaw/Kilmeaden	38	Portlaw, Kilmeaden	48.750	00:07	10:24	10:31
Butlerstown	Tramore	38	Tramore	48.800	00:07	10:24	10:31
Carlow	Ballylinan Rd	38	Ballylinan Rd	48.800	00:49	10:24	11:13
Carlow	Graigue	38	Graigue	48.550	00:21	10:27	10:48
Carlow	Pollerton	38	Pollerton	48.550	00:20	10:27	10:47
Carlow	Tullow	38	Tullow	48.750	00:20	10:25	10:45
CK-ON-SH	Castlerea	38	Castlerea	48.700	00:04	10:26	10:30
CK-ON-SH	Mohill	38	Mohill, Carrigallen	48.800	00:06	10:24	10:30
Drybridge	Slane	38	Slane	48.800	00:14	10:25	10:39
Dungarvan	Kilmacthomas	38	Kilmacthomas	48.800	00:20	10:24	10:44
Dunmanway	Clonakilty	38	Clonakilty, Timoleague	48.600	00:16	10:27	10:44
Dunmanway	Currabwee/Skibbereen	38	Currabwee, Skibbereen, Roscarbery	48.600	00:35	10:26	11:02
Dunmanway	Lake	38	Lake	48.800	00:20	10:24	10:44
Ennis	Cahercalla	38	Cahercalla, Clarecastle	48.550	00:21	10:27	10:48
Ennis	Corroworrin	38	Corroworrin	48.550	00:21	10:27	10:48
Ennis	Drumquin, Cranny	38	Drumquin, Cranny	48.850	01:11	10:24	11:35
Ennis	Gort	38	Gort	48.850	00:0	10:24	10:24

110kV Station	Feeder	kV	Stations on outlet	Setting on 8-5-05	Actual time down	Time Out	Time Restored
					0		
Ennis	Tulla	38	Tulla, Scariff	48.700	00:45	10:24	11:09
FASSAROE	Greystones/Kilcoole	38	Greystones/Kilcoole	48.600	00:16	10:26	10:42
FINGLAS	Ashbourne	38	Ashbourne	48.700	00:19	10:26	10:45
FINGLAS	Ballymun T41	38	Ballymun T41	48.600	00:15	10:26	10:41
FINGLAS	Merville T41 + T42	38	Merville T41 + T42	48.600	00:04	10:26	10:30
GLASMORE	Mountgorry	38	Mountgorry	48.900	00:35	10:24	10:59
GRANGE	Grange T41	38	Grange T41	48.800	00:37	10:24	11:01
GRANGE	Grange T42	38	Grange T42	48.800	00:37	10:24	11:01
GRANGE	MONTGORRY	38	MONTGORRY	48.900	00:34	10:24	10:58
Great Island	Bealistown	38	Bealistown, New Ross, Rosbercon	48.850	01:06	10:24	11:30
INCHICORE	Inchicore Central T45	38	.Inchicore Central T45	48.800	00:36	10:24	11:00
INCHICORE	Greenhills T42	38	Greenhills T42	48.425	00:14	10:27	10:41
INCHICORE	Templeogue T41 + T42	38	Templeogue T41+T42	48.800	00:13	10:25	10:38
INCHICORE	.Inchicore T43	38	.Inchicore T43	48.900	00:36	10:24	11:00
Kilbarry	Whitechurch	38	Whitechurch	48.900	00:24	10:24	10:48
Kilkenny	Ballyhale	38	Ballyhale	48.850	00:14	10:24	10:38
Kilkenny	Ballyragget	38	Ballyragget, Castlecomer	48.500	00:16	10:27	10:44
Kilkenny	Callan	38	Callan	48.850	00:14	10:24	10:38
Kilkenny	Goresbridge	38	Goresbridge, Graiguenamanagh	48.800	00:15	10:24	10:39
Knockearag	Kilgarvan	38	Kilgarvan and	48.700	00:1	10:25	10:40

110kV Station	Feeder	kV	Stations on outlet	Setting on 8-5-05	Actual time down	Time Out	Time Restored
h			Kenmare		4		
Letterkenny	Convoy	38	Convoy, Stranorlar	48.600	00:21	10:27	10:48
Limerick	South Hill	38	Southill	48.500	00:45	10:27	11:13
Mallow	Buttevant	38	Buttevant	48.900	00:16	10:24	10:40
Mallow	Fermoy N/Castletownroche	38	Castletownroche	48.900	00:23	10:24	10:47
MCDERMOTT	Clontarf T42	38	Clontarf T42	48.700	00:13	10:25	10:38
MCDERMOTT	Fairview T41	38	Fairview T41	48.700	00:36	10:25	11:01
MOY	Crossmolina	38	Crossmolina	48.900	00:21	10:25	10:46
Navan	Athboy	38	Athboy	48.900	00:12	10:26	10:38
Newbridge	Kildare	38	Kildare	48.900	00:15	10:24	10:39
Portlaoise	Stradbally Road	38	Stradbally Road	48.700	00:52	10:24	11:16
Portlaoise	Kildare	38		48.9	00:14	10:24	10:38
Shankill	Clones	38	Clones	48.900	00:14	10:24	10:38
Tipperary	Kilross Road, Garranacanty	38	Kilross Road, Garranacanty	48.750	00:22	10:25	10:48
Tralee	Kilflynn	38	Kilflynn, Causeway	48.800	00:15	10:24	10:39
Tullabrack	Kilrush	38	Kilrush, Kilkee	48.700	01:08	10:26	11:35
Tullabrack	Milltown Malbay	38	Milltown Malbay	48.900	00:42	10:45	11:27
Wexford	Carriglawn	38	Carriglawn	48.600	00:58	10:24	11:22
Wexford	Monfin	38	Monfin, Clonroche	48.650	00:55	10:25	11:21
Wexford	Mulgannon/Barntown	38	Mulgannon, Barntown	48.600	01:01	10:24	11:25

Feeder which should not have tripped: Under frequency setting not reached

110kV Station	Feeder	kV	Stations on outlet	Setting on 8-5-05	Actual time down [m]	Time Out	Time Restored
FINGLAS	Clontarf T42	38	Clontarf T42	48.125	00:13	10:25	10:38
FINGLAS	Fairview T41	38	Fairview T41	48.125	00:36	10:25	11:01
INCHICORE	Liffey Valley 10kV CB's	MV	Liffey Valley	48.300	00:11	10:27	10:38
MACETOWN	K-Series Relays on all 10kV Outlets	MV	K-Series Relays on all 10kV Outlets	48.120	00:35	10:26	11:01
MILLTOWN	Donnybrook T41 + T42	38	Donnybrook T41 + T42	48.250	00:12	10:27	10:39

Appendix 2: Restoration details
Feeders with correct Automatic Restoration

110kV Station	Feeder	kV	Stations on outlet	Setting on 8-5-05	Actual time down
Ardnacrusha	Birdhill	38	Birdhill, Tyone	48.65	00:21
Ardnacrusha	Cappamore	38	Cappamore	48.75	00:21
Ardnacrusha	Cratloe/Caherdavin	38	Cratloe	48.80	00:19
Ardnacrusha	Gillogue	38	Gillogue	48.50	00:21
Arklow	Rathdrum/Kilmartin/Wicklow	38	Kilmartin	48.90	00:25
Athlone	Ballygar	38	Ballygar	48.80	00:16
Athlone	Moate	38	Moate	48.80	00:21
Binbane	Glenties	38	Glenties	48.50	00:21
BLACKROCK	Ballinaclea T41	38	Ballinaclea T41	48.70	00:16
BLACKROCK	Sallynoggin T41/T42	38	Sallynoggin T41/T42	48.80	00:15
Butlerstown	Grange	38	Grange	48.50	00:58
Butlerstown	Portlaw/Kilmeaden	38	Portlaw, Kilmeaden	48.75	00:07
Butlerstown	Tramore	38	Tramore	48.80	00:07
Carlow	Ballylinan Rd	38	Ballylinan Rd	48.80	00:49
Carlow	Graigue	38	Graigue	48.55	00:21
Carlow	Pollerton	38	Pollerton	48.55	00:20
Carlow	Tullow	38	Tullow	48.75	00:20
Drybridge	Slane	38	Slane	48.80	00:14
Dungarvan	Kilmacthomas	38	Kilmacthomas	48.80	00:20
Dunmanway	Clonakilty	38	Clonakilty, Timoleague	48.60	00:16
Dunmanway	Lake	38	Lake	48.80	00:20
Ennis	Drumquin, Cranny	38	Drumquin, Cranny	48.85	01:11
Ennis	Tulla	38	Tulla, Scariff	48.70	00:45
Ennis	Cahercalla	38	Cahercalla, Clarecastle	48.55	00:21
Ennis	Corroworrin	38	Corroworrin	48.55	00:21
Ennis	Gort	38	Gort	48.85	00:00

110kV Station	Feeder	kV	Stations on outlet	Setting on 8-5-05	Actual time down
FASSAROE	Greystones/Kilcoole	38	Greystones/Kilcoole	48.60	00:16
FINGLAS	Ashbourne	38	Ashbourne	48.70	00:19
FINGLAS	Ballymun T41	38	Ballymun T41	48.60	00:15
FINGLAS	Clontarf T42	38	Clontarf T42	48.125	00:13
INCHICORE	Greenhills T42	38	Greenhills T42	48.43	00:14
INCHICORE	Templeogue T41 + T42	38	Templeogue T41 + T42	48.80	00:13
INCHICORE	Liffey Valley 10kV CB's	MV	Liffey Valley	48.30	00:11
INCHICORE	.Inchicore T43	38	.Inchicore T43	48.90	00:36
Kilbarry	Whitechurch	38	Whitechurch	48.90	00:24
Kilkenny	Ballyhale	38	Ballyhale	48.85	00:14
Kilkenny	Ballyragget	38	Ballyragget, Castlecomer	48.50	00:16
Kilkenny	Callan	38	Callan	48.85	00:14
Kilkenny	Goresbridge	38	Goresbridge, Graiguenamanagh	48.80	00:15
Knockearagh	Kilgarvan	38	Kilgarvan and Kenmare	48.70	00:14
Letterkenny	Convoy	38	Convoy	48.60	00:21
Mallow	Buttevant	38	Buttevant	48.90	00:16
Mallow	FermoyNth/Castletownroche	38	Castletownroche	48.90	00:23
MCDERMOTT	Clontarf T42	38	Clontarf T42	48.70	00:13
MCDERMOTT	Fairview T41	38	Fairview T41	48.70	00:36
MILLTOWN	Donnybrook T41 + T42	38	Donnybrook T41 + T42	48.250	00:12
MOY	Crossmolina	38	Crossmolina	48.90	00:21
Newbridge	Kildare	38	Kildare	48.90	00:15
Portlaoise	Stradbally Road	38	Stradbally Road	48.70	00:52
Portlaoise	**Kildare**	**38**		**48.9**	**00:14**
Shankill	Clones	38	Clones	48.90	00:14
Tipperary	Kilross Road, Garranacanty	38	Kilross Road, Garranacanty	48.75	00:22
Tralee	Kilflynn	38	Kilflynn, Causeway	48.80	00:15

110kV Station	Feeder	kV	Stations on outlet	Setting on 8-5-05	Actual time down
Tullabrack	Kilrush	38	Kilrush, Kilkee	48.70	01:08
Tullabrack	Milltown Malbay	38	Milltown Malbay	48.90	00:42
Wexford	Carriglawn	38	Carriglawn	48.60	00:58
Wexford	Monfin	38	Monfin, Clonroche	48.65	00:55
Wexford	Mulgannon/Barntown	38	Mulgannon, Barntown	48.60	01:01

Table 4 : Feeder with correct auto restoration

Feeder that restored too quickly

110kV Station	Feeder	kV	Stations on outlet	Setting on 8-5-05	Actual time down
CK-ON-SH	Castlerea	38	Castlerea	48.70	00:04
CK-ON-SH	Mohill	38	Mohill	48.80	00:06
FINGLAS	Merville T41 + T42	38	Merville T41 + T42	48.60	00:04
Navan	Athboy	38	Athboy	48.90	00:12

Table 5: Feeders restored too quickly

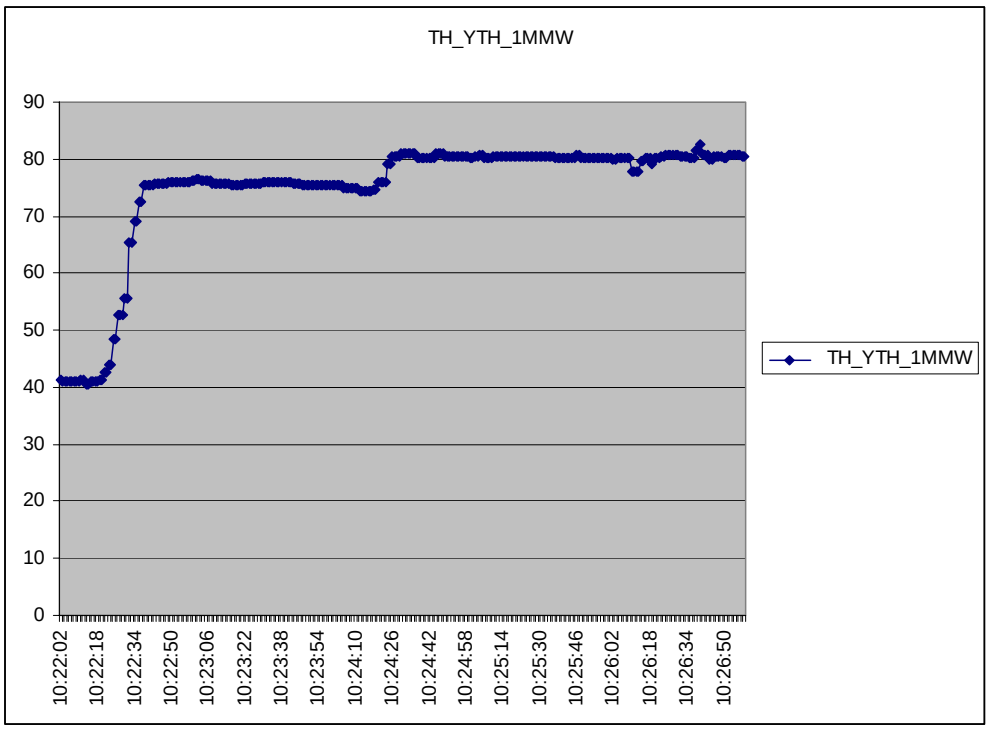
Feeders requiring manual restoration

110kV Station	Feeder	kV	Stations on outlet	AFR installed	Setting on 8-5-05	Actual time down
Ardnacrusha	Bruff	38	Bruff	NO	48.85	00:50
Ardnacrusha	Moylish	38	Moylish, Caherdavin	NO	48.80	02:27
Ardnacrusha	Southill	38		NO	48.55	00:46
Ardnacrusha	Tulla	38		NO	48.70	00:55
BELLACORICK	Bangor Erris	38	Bangor Erris, Belmullet	NO	48.80	01:06
Dunmanway	Currabwee/Skibbereen	38	Currabwee, Skibbereen, Roscarbery	YES	48.60	00:35
FINGLAS	**Fairview T41**	**38**	**Fairview T41**	**YES**	**48.125**	**00:36**
GLASMORE	Mountgorry	38	Mountgorry	YES	48.90	00:35
GRANGE	Grange T41	38	Grange T41	YES	48.80	00:37
GRANGE	Grange T42	38	Grange T42	YES	48.80	00:37
GRANGE	MONTGORRY	38	MONTGORRY	YES	48.90	00:34
Great Island	Bealistown	38	Bealistown, New Ross, Rosbercon	NO	48.85	01:06

110kV Station	Feeder	kV	Stations on outlet	AFR installed	Setting on 8-5-05	Actual time down
INCHICORE	Inchicore Central T45	38	.Inchicore Central T45	YES	48.80	00:36
Limerick	South Hill	38	Southill	YES	48.50	00:45
MACETOWN	K-Series Relays on all 10kV Outlets	MV	K-Series Relays on all 10kV Outlets	YES	48.120	00:35

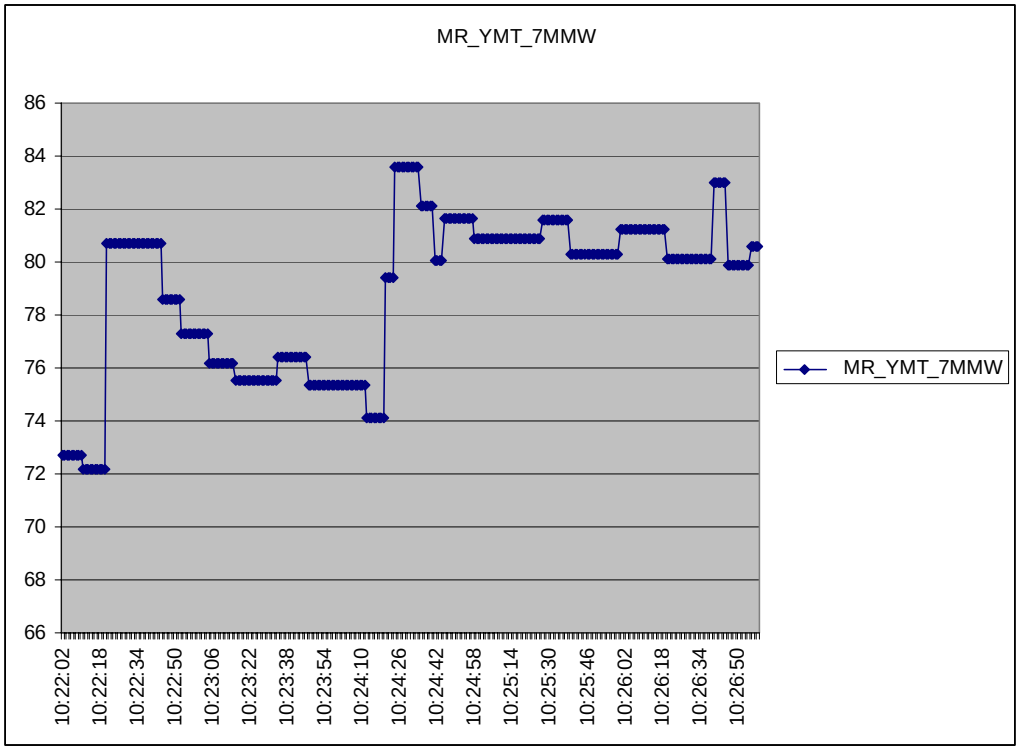
Table 6 : Feeders failed to auto-restore

Appendix 5 – Sample generator responses to event



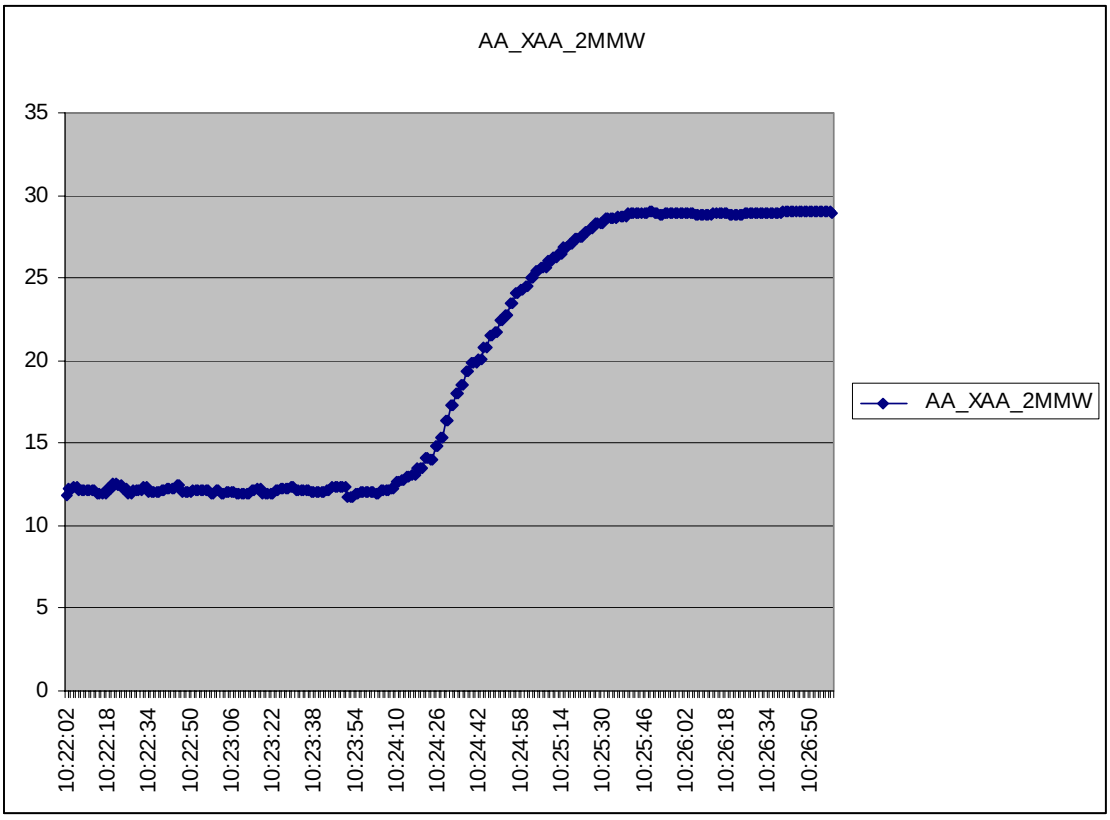
Output of Turlough Hill Unit 1 pumped storage generator during the event.

As can be seen from this graph, this unit rose automatically from 42.5 MW at 10.22.22 hrs to 75.4 MW by 10.22.40 and rose further to 80.9 MW in response to the second frequency drop. This unit has a name-plate rating of 73 MW.



Output of Marina Combustion Turbine generator during the event.

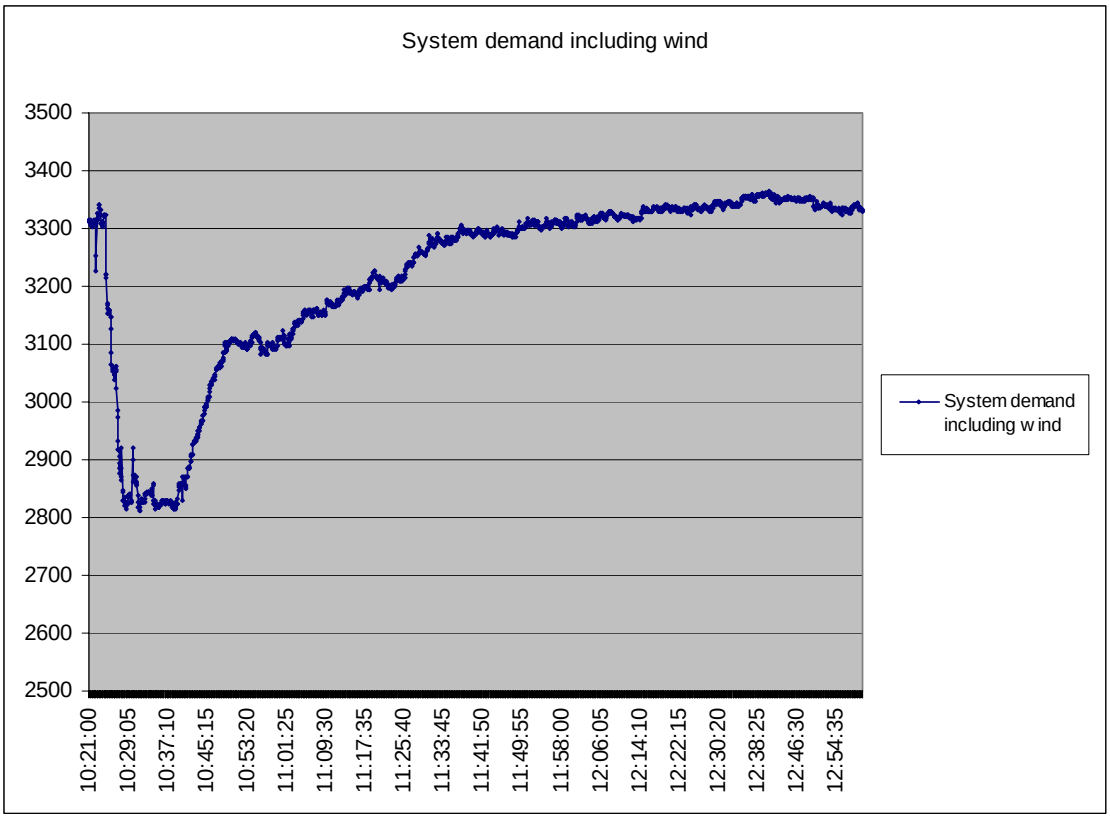
As can be seen from this graph, this unit rose initially from 72 MW to 81 MW, delivering an inertial response. It had settled down to 74 MW prior to the second frequency drop when it delivered an inertial response to 84 MW. It then levelled out at 80 MW, 8 MW above its pre-event output.



Output of Ardnacrusha Unit 2 hydro generator during the event.

This unit rose initially from 12 .5 MW pre-fault to 29 MW.

Appendix 6 – System Demand during event



The graph above plots the variation in system demand during the event. As can be seen, load shedding of 500 MW approximately occurred.

Appendix 7 - list of out-of-service transmission plant prior to the event

Louth-Tandragee 1 275 kV line
Louth AT1 220/275 kV transformer
Louth AT3 220/275 kV transformer
Oldstreet – Woodland 400 kV line
Finglas – Woodland 4 220 kV line
Carrickmines – Dunstown 220 kV line
Killonan - Tarbert 220 kV line
Corduff - Finglas 1 220 kV line
Knockraha T2102 220/110 kV transformer
Louth – Mullagharlin 110 kV line
Cushaling – Portlaoise 110 kV line
Drumkeen – Letterkenny 110 kV line
Castleview – Cow Cross 110 kV line
Derryiron – Thornsberry 110 kV line
Grangecastle – Griffinrath – Maynooth 110 kV line
Carlow – Pollaphuca -Stratford 110 kV line
Castleview – Cow Cross 110 kV line
Aughinish – Tarbert 110 kV line
Cunghill – Moy 110 kV line

Appendix 8 – Operating Reserve

Every Transmission System Operator ensures the provision of operating reserve to mitigate the effects of the sudden failure of a large generator. Generators on the Irish power system are very large relative to the system size, and their sudden failure has a far greater impact, as can be seen by the fall in power system frequency, than is the case in large interconnected power systems such as Europe or even Britain. However, the provision of operating reserve adds to the final price of electricity and therefore a balance must be found – a balance between mitigating the effects of the sudden loss of generation and containing the cost of electricity.

ESB National Grid believes that the correct balance has been found for Ireland. Occasionally, events occur which cause temporary interruption in supply to some customers. These interruptions are usually short in duration as automatic restoration of supply is a feature of the Irish power system. [Supply is also interrupted from time-to-time for “non-grid” events such as failures in the distribution networks].

It has been suggested that more operating reserve should be provided when one of the two limbs of the Louth-Tandragee 275 kV interconnector is out of service so as to guard against the loss of the interconnector. This would increase the price of electricity to the customer and appears to ESB National Grid to be unwarranted as the loss of the interconnector is a highly unlikely event and did not in fact occur on this occasion.

Delivery of operating reserve is monitored by ESB National Grid – the reserve delivery during this event by a sample of generators is contained in Appendix 5. Generators are penalised when they fail to deliver the expected amount of reserve following an event. Continuous monitoring of the ability to provide reserve is more difficult as this ability is proven when the power system is under stress following an event and when the frequency is lower than normal – a situation which the Transmission System Operator is prudently reluctant to create artificially for test purposes. ESB National Grid is examining ways to improve real-time reserve monitoring under normal system conditions. Connecting generators are put through grid code compliance tests at the time of commissioning.

To	NDCC, Projects North, Projects Dublin	Copies To	NCC, OCE
From	Power System Control, National Grid	Ref No.	VO 01 / 31 (b2004)
Subject	Outage of in Louth - Tandragee 1 (One) 275kV line and AT1 and AT3 Transformers		

FROM: TO :	07.30 Monday, 1st August 2005 17.00 Sunday, 14th August 2005	
Station In Charge	Louth	Outage IDs : TO-05-LOU-TAN-1-01 & TO-05-LOU-AT1-01 & TO-05-LOU-AT3-01 Op in Charge : 'to be appointed by Pat Malone at Louth 220kV stn' Operators will be appointed by : 'P Malone'
Reason	Line : maintenance (p155525) Replace insulators AT1 : OS (p138252) Oil regeneration – reconditioning (c101147) 220kV cubicle : inspect u-carriage clevis pins (c120129) OS (p138250) CA (p137220) 275kV cubicle : OS (p110272) AT3 : OS (p138262) Oil regeneration – reconditioning (c101148) Tap change inspection (p137222) 220kV cubicle : inspect u-carriage clevis pins (c120140) OS (p138260) 275kV cubicle : CA (p137227) OS (p138239)	
Plant Availability	24 hours	

Operational Notes:	Before Outage 1. Points of disconnection and isolation should be agreed between NIE CHCC and Louth 220kV stn prior to switching out circuit. 2. The switching should follow the procedures as laid out in the Operating and Commercial Agreements for Louth-Tandragee interconnector No.4 switching instructions. 3. Earthing is required in Tandragee and Louth 4. The Louth-Tandragee 2 (Two) 275kV circuit must be in service.	
ESB point of contact in Louth	Name Pat Lee	Number 087 797 5926

DOF:	From ESBI: Louth - Tandragee 1 (One) 275kV line Louth AT1 transformer Louth AT3 transformer
Signed:	Brendan Reid For Manager, Power System Control