

## NATIONAL GRID

### **Report of the investigation into the automatic demand disconnection following multiple generation losses and the demand control response that occurred on the 27<sup>th</sup> May 2008**

*This report has been produced by National Grid to record the findings of an investigation into the automatic demand disconnection following multiple generation losses and demand control response. The purpose of the report is to enable National Grid to identify (if possible) the cause or causes of the incident so that it may seek to prevent a recurrence. The purpose of the report is not, however, to identify legal liability; therefore the data and information contained within it have not been compiled in accordance with rules of evidence and cannot be seen as determining either the Group's or an individual's legal liability.*

*This report has been prepared for DBERR and Ofgem in a form that may be placed in the public domain and, accordingly, in accordance with obligations placed upon National Grid, it does not at this stage contain information that relates to a particular business*

*All references in this document to "National Grid" refer to National Grid Electricity Transmission plc, the electricity Transmission licence holder.*

## **Contents**

1. Introduction
2. Summary
3. Industry Frameworks Relevant to the Events of 27<sup>th</sup> May 2008
  - 3.1 National Grid's Role as GB System Operator: Frequency Control and System Operating Margin
  - 3.2 Roles of Generators and Distribution Network Operators
4. 27<sup>th</sup> May Sequence Of Events
  - 4.1 Background
  - 4.2 Operating Margins and Generation Availability
  - 4.3 Generation Loss Incident
  - 4.4 Automatic Demand Disconnection and Frequency Recovery
  - 4.5 Recovery To Normal Operating Conditions
5. Preliminary Findings and Interim Conclusions
  - 5.1 Performance of Transmission Contracted Generation Plant
  - 5.2 Performance of Embedded Generation Plant
  - 5.3 Performance of National Low Frequency Demand Disconnection Scheme and Associated Low Frequency Relays
  - 5.4 Performance of Demand Control by Voltage Reduction
  - 5.5 System Operational Margins and Frequency Excursion
  - 5.6 Communications with the Market, Generators and Distribution Network Operators
6. Further Work In Progress
  - 6.1 Performance of Transmission Contracted Generation Plant
  - 6.2 Performance of Embedded Generation Plant
  - 6.3 Performance of Low Frequency Demand Disconnection Scheme and Associated Low Frequency Relays
  - 6.4 Demand Control by Distribution Network Operators
  - 6.5 Progress of Issues Raised by this Event
7. **Appendices**
  - Appendix 1: Grid Code Low Frequency Demand Disconnection (LFDD) Scheme
  - Appendix 2: Copy of Hyperlink references used in this report

## **1. Introduction**

- 1.1 On the 27<sup>th</sup> May 2008 an exceptional loss of some 1582MW of generation within two minutes (11:34am and 11:36am) resulted in a major system disturbance. The immediate effect of this loss was to take the system out of normal operating conditions which eventually led to the triggering of automatic low frequency relays to preserve the integrity of the wider electricity system. As a consequence some 581MW of demand was automatically shed at 11:37am.
- 1.2 This very significant generation loss coupled with the pattern of other within day losses, and in particular the level of generation loss from 2 hours ahead of real time, led to a shortage of generation, the use of system warnings by National Grid under the Grid Code and the application of demand control across up to nine Distribution Network Operator (DNOs) regions at any one time.
- 1.3 Whilst detailed work continues, this report provides a summary of events and interim conclusions. National Grid will continue to work with the industry to determine if there are lessons to be learnt for the future, which will be taken forward through the Energy Emergencies Executive Committee (E3C) and the Grid Code Review Panel (GCRP).

## **2. Summary**

- 2.1 Prior to the day the forecast demand and generation levels were recorded as being healthy and not at all unusual. The events that occurred throughout the day, both before and after the automatic disconnection of demand event, which are described in this report, make 27th May exceptional on two counts. Firstly, the loss of such a large amount of demand as a result of the operation of low frequency relays is exceptional in historic terms and secondly the total level of generation lost within such a short period is also unusual.
- 2.2 On the morning of 27th May an unrelated and near simultaneous loss of generation at Generator A (345MW at 11.34am) and Generator B (1237MW at 11.36am), totalling some 1582MW at the time of loss, gave rise to a drop in system frequency to 49.14Hz. Following this there was a further, as yet not fully explained loss, which led to a further drop in system frequency to 48.795Hz. Theoretical analysis undertaken so far suggests that this last excursion could have been triggered by a further combined generation loss of around 250MW or more. These generation losses resulted in system frequency being outside of National Grid's operational criteria and statutory limits for 11 and 9 minutes respectively.
- 2.3 Given the dropping frequency, and in order to prevent wider-scale losses of supply, a number of automatic low frequency relays operated at 48.8Hz to arrest the fall and in doing so disconnected some 581MW of demand (estimated as some 580,000 customers). Following this National Grid, in conjunction with the market, were able to recover the system frequency and instructed all affected Distribution Network Operators (DNOs) to restore the automatically disconnected

demand within a range of 20 to 40 minutes, although given the actions needed by some DNOs some customers were off supply for up to 63 minutes.

- 2.4 The loss of this generation, together with the pattern of significant other within day plant losses lead to a tight supply margin position throughout the afternoon which required the issue of system warnings by National Grid under the Grid Code, namely notices for both High Risk of Demand Reduction (HRDR) and Demand Control Imminent (DCI).
- 2.5 In order to achieve the necessary generation/demand balance a number of DNOs were instructed to apply demand control throughout the afternoon and over the evening peak, as a result of which normal operating margins were re-established by early evening. System conditions for the remainder of the week were normal.
- 2.6 The level of generation capacity loss experienced (2253MW) is a level that would only be experienced once in every 4 to 5 years based on historic data. As a result of the exceptional generation loss, the use of demand control for the afternoon period is as would be anticipated by the operating standards
- 2.7 This report seeks to give a summary of the events of the day. Further work initiated by National Grid will provide more detail on the performance of the Transmission System, Generation and the Distribution Networks.
- 2.8 In particular National Grid has sought information from the DNOs to facilitate analysis of:
  - the performance of embedded generation
  - the actual demand tripped by the low frequency relays and the performance of those relays
  - the actual demand relief delivered by the manually instructed demand control
- 2.9 Following this work National Grid will be able to further validate the findings of this report and, as necessary, make recommendations in respect of further work required which will be taken forward through the Energy Emergencies Executive Committee (E3C) and the Grid Code Review Panel (GCRP).

### **3. Industry Frameworks Relevant to the Events of 27<sup>th</sup> May 2008**

#### **3.1 National Grid's Role as GB System Operator (GBSO): Frequency Control and System Operating Margin**

##### **GB System Operator (GBSO)**

- 3.1.1 National Grid is responsible for the management of Transmission network security and real time balancing of generation with demand in our role of GB System Operator. Any imbalance between generation input and demand will result in perturbations in the nominal system frequency of 50Hz.

##### **Frequency Control Requirements**

- 3.1.2 National Grid manages the system frequency to defined Statutory steady state limits of  $\pm 0.5\text{Hz}$  (i.e. 49.5Hz to 50.5Hz) and our Operational limits of  $\pm 0.2\text{ Hz}$  (i.e. 49.8Hz to 50.2Hz).

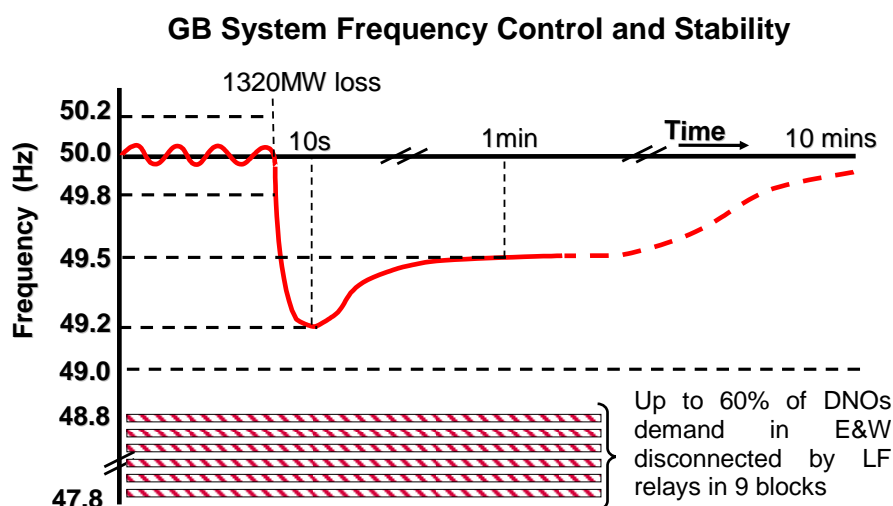
- 3.1.3 The [GB Security and Quality of Supply Standard \(GB SQSS\)](#) specifies the limits of frequency deviations for secured faults, which include loss of output from a single generating unit, Combined Cycle Gas Turbine Module (CCGT), boiler, nuclear reactor or DC bi-pole lost as a result of an event. These limits are:

- Normal Infeed Loss Risk (1000MW): Maximum frequency deviation should not exceed 0.5Hz
- Infrequent Infeed Loss Risk (1320MW): Frequency should not deviate outside the range 49.5Hz to 50.5Hz for more than 60 seconds.

The largest infrequent infeed loss of 1320MW is derived from the largest possible generation infeed loss on the Transmission system that will result from a single event.

- 3.1.4 In the case of Infrequent Infeed Loss Risk, National Grid's practice is to ensure that the maximum frequency deviation is limited to 0.8Hz. In addition, National Grid aims to return the frequency to operational limits (49.8Hz to 50.2Hz) within 10 minutes.
- 3.1.5 For a larger generation loss than the Infrequent Infeed Loss Risk or a large generation deficit in an importing power island following a sudden system split, the National Low Frequency Demand Disconnection (LFDD) scheme (as described in Grid Code OC6.6) is designed to automatically disconnect demand to contain the incident and prevent a total or partial shutdown of the power system.

**FIGURE 1**



3.1.6 Figure 1 illustrates the frequency control philosophy and frequency stability of the GB power system. In addition, where the initial frequency is close to the lower operational limit of 49.8Hz at the time of a 1320MW loss, the lowest planned frequency would be 49Hz. This would still restrict the maximum frequency deviation to 0.8Hz and provide a 0.2Hz margin above the level where the LFDD scheme is designed to operate and disconnect demand.

### System Operating Margin

3.1.7 Looking ahead of real time, and in recognition of variability and uncertainty of demand for electricity and that statistically some generating plant will break down, National Grid will, at all times, hold a “safety cushion” or “operating margin”. This will be generation capacity (or demand reduction) available to us, on instruction, in varying timescales (from minutes to hours ahead of real time) to ensure that for all secured events, we can access sufficient generation output to meet the forecast demand.

3.1.8 The safety cushion comprises 4 main components:

- Contingency Reserve – generation plant available at between 4 and, typically, 12 hours notice to generate
- Short Term Operating Reserve – generation (or demand) typically available to respond within 5 – 20 minutes
- Regulating Reserve – generation that is synchronised with capacity to enable us to instruct increases (or decreases) in output to assist with short term demand forecast errors or plant losses
- Frequency Response – generation that automatically changes output to help with correction of frequency deviations

3.1.9 The actual size of the “contingency reserve” varies according to time of day, time of year and demand forecast, but for any particular point

in the day the requirement decreases as real time approaches, typically ranging from some 1000MW at 24 hours ahead to zero by 4 hours ahead.

3.1.10 The Grid Code describes 3 System Warnings that are relevant to the 27<sup>th</sup> May. These are:

- **GB Transmission System Warning – Inadequate System Margin** – issued when there is inadequate System Margin (as referred to in Grid Code Balancing Code BC1.5.4) and it is uncertain if this would be recovered over the relevant timescales. This warning was previously referred to as a NISM (Notification of Inadequate System Margin Warning)
- **High Risk of Demand Reduction (HRDR)** – issued when there is inadequate System Margin (as referred to in Grid Code Balancing Code BC1.5.4) and/or it is judged to be a high risk of demand reduction being instructed
- **Demand Control Imminent (DCI)** – issued to provide short term notice, where possible, when a demand reduction is expected in the following 30 minutes

3.1.11 National Grid's dispatch of reserve is described in detail in National Grid's [Balancing Principles statement](#). Our existing policy which has been in place since NETA aims to hold sufficient reserve such that the net impact of generation loss and demand forecast error is only violated once per year, thus we would expect to utilise demand control as described in the Grid Code (see 3.2.5 below) on one occasion per year. This policy has been [described in detail](#) at a number of industry events.

## 3.2 Roles of Generators and Distribution Network Operators

### Generators

3.2.1 As many generation losses are by nature sudden and unexpected, National Grid contracts for automatic, commercial services ("frequency response") from generators and demand side participants which will deliver immediate changes to output to maintain the system frequency within the required limits.

3.2.2 The Grid Code Connection Condition (CC) 6.3 requires that Generators have a frequency response capability and Balancing Code 3 of the Grid Code sets out the procedure for National Grid to use in conjunction with Users of the Transmission system (including Generators) to undertake system frequency control provision.

3.2.3 All Generators are required to operate either in Frequency Sensitive Mode or Limited Frequency Sensitive Mode at all times. When operating in Frequency Sensitive Mode, Generators are required to comply with Grid Code CC6.3.7 and their ancillary service contracts in relation to the MW output response delivered. When operating in Limited Frequency Sensitive Mode, Generators are required to comply with Grid Code CC6.3.3 that governs their MW output changes in response to system frequency changes.

3.2.4 Furthermore, the Grid Code CC6.1.3 recognises that generation must be able to continuously operate in the range of 47.5Hz to 52Hz, and be able to operate for a period of at least 20 seconds in the range 47Hz to 47.5Hz. The Grid Code applies to all Transmission connected generation, and all generation in:

- England and Wales  $\geq 50\text{MW}$
- Scottish Power Transmission Ltd region  $\geq 30\text{MW}$
- Scottish Hydro-Electric Transmission Ltd region  $\geq 10\text{MW}$

Generally, all DNO connected generation less than these values will be required to comply with the relevant Distribution Code and Engineering Recommendations G75 and G59/1. Both of these Engineering Recommendations recommend a low frequency threshold of 47Hz.

### **Distribution Network Operators**

3.2.5 Grid Code Operating Code (OC) No 6, (Demand Control) is concerned, amongst other things, with the provisions to be made by DNOs to permit the reduction of demand in the event of insufficient active power generation being available to meet demand.

3.2.6 Grid Code OC6.5 describes the procedure for the implementation of Demand Control by the DNOs on the instruction of National Grid. The required demand reduction will be achieved at all times, with or without prior warning, within agreed timescales (as per Grid Code OC6.7.3) upon receipt of an instruction from National Grid.

3.2.7 Grid Code OC6.6 describes the automatic Low Frequency Demand Disconnection scheme and the arrangements that the DNOs are required to make in relation to this scheme. Grid Code CC.A.5.5.1 specifies the technical characteristics of low frequency relays. Following operation of this scheme, DNOs are not permitted to restore automatically disconnected demand without instruction from National Grid.

## **4 27<sup>th</sup> May Sequence of Events**

### **4.1 Background**

4.1.1 This report deals predominantly with the events close to real time as this is the time frame relevant to the events of 27<sup>th</sup> May 2008. National Grid undertakes a wide range of planning and analysis of system security at longer lead times and provides a range of information to the market through established mechanisms (e.g. Generation Margin reports and the Winter and Summer Outlook reports).

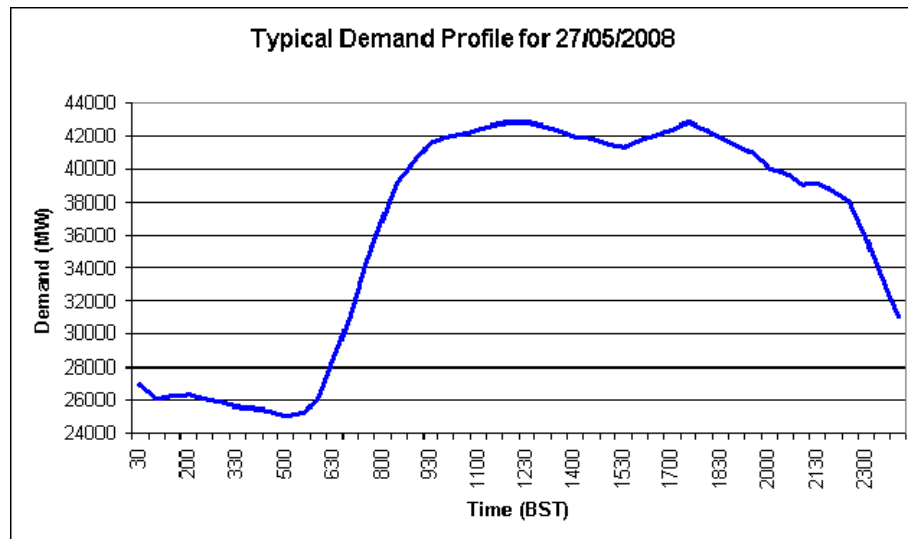
4.1.2 Within shorter term timescales, the Electricity National Control Centre (ENCC) from approximately 11:00am at the day-ahead stage, monitors and takes appropriate action to ensure that the operating



conditions for the following day are within the required operating standards.

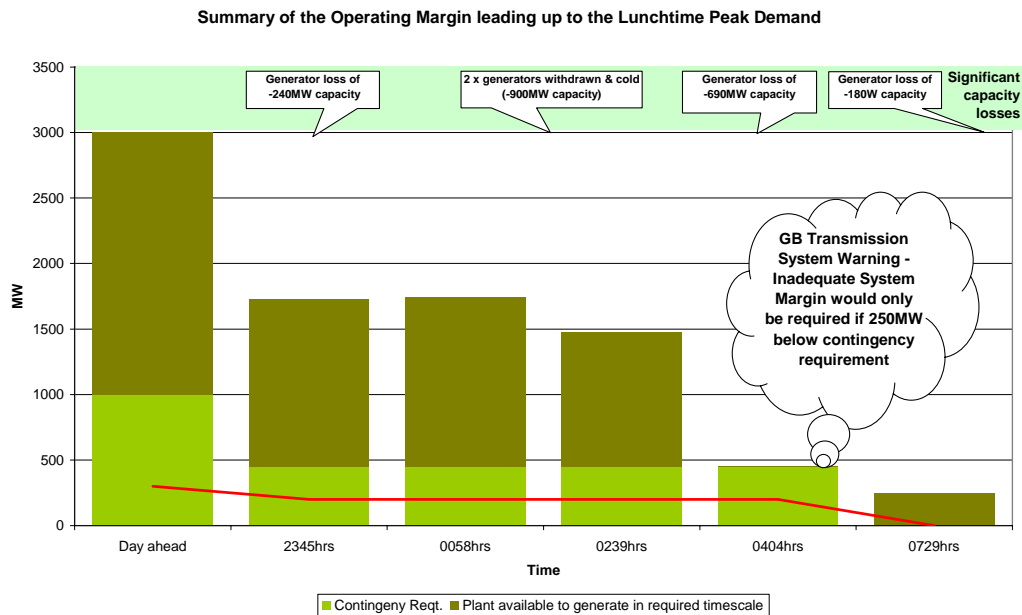
- 4.1.3 Figure 2 below summarises the shape of the demand curve for Tuesday 27<sup>th</sup> May. The forecast for the Peak demand was to be 43GW, at 5:00pm, with the lunchtime peak being slightly lower at 42.2GW at approximately 12:15pm. Planned operating conditions, based on information received from suppliers and generators, together with the anticipated configuration of the Transmission system were within normal operating parameters in the period leading to the event.
- 4.1.4 There were few active Transmission constraints that would significantly impact generation operation on this day. The primary exception being the capability on that day across the Scotland-England border. This would limit the maximum export to England however, forecast flows on this boundary were within acceptable limits.

**FIGURE 2**



## **4.2 Operating Margins and Generation Availability**

- 4.2.1 Figure 3 summarises the generation plant available to meet the peak lunchtime demand from the day ahead to 4 hours ahead of real time, when the requirement for the “contingency reserve” margin reduces to zero. From 4 hours ahead of real time, the generation/demand uncertainty is managed by utilising short term operating reserve, regulating reserve and/or frequency response.
- 4.2.2 Generation plant known to be available to synchronise and achieve full output by the lunchtime peak demand is also indicated in Figure 3. It should be noted that National Grid might be required to intervene to retain this capability to synchronise within the required timescales. Figure 3 also indicates the required “contingency reserve” margin at the identified times.

**FIGURE 3**

4.2.3 Figure 3 reveals that National Grid's minimum contingency reserve requirements were met at all times during the period leading up to the loss of both Generator A and Generator B. Following the loss of generation capacity overnight (as referenced in Figure 3 above) one unit was planned to re-synchronise at 0910am. However, in the period from 07:30am to 11:34am, a number of further generation losses were observed totalling some 1240MW, (although approximately 300MW had recovered by 09:00am)

4.2.4 The ENCC responded by instructing once coal generating unit (480MW generation capacity) to synchronise at 09:55am and placing another coal generating unit on hot standby, which would enable it to be called to generate within shorter timescales should it be required later in the morning. Some 470MW of commercial Standing Reserve and interconnector services were initiated to assist in the period 08:54am to 09:36am to help cover for the combined generation losses encountered.

4.2.5 As illustrated in Figure 3, the levels of generation available remained above that which would trigger National Grid to issue a GB Transmission System Warning – Inadequate System Margin.

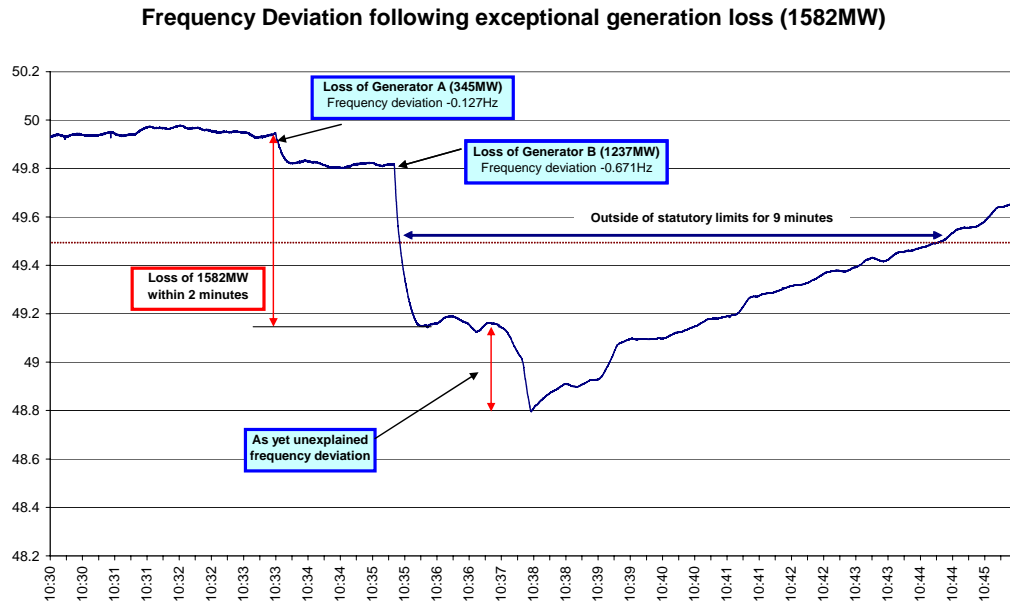
4.2.6 Throughout the morning, ENCC had instructed the appropriate levels of Regulating Reserve and Frequency response to ensure compliance with required standards and secure the system to the largest single loss, which on that day was Generator B (1237MW).

### 4.3 Generation Loss Incident

4.3.1 Figure 4 illustrates the impact to the system frequency as a result of the Generator A and Generator B losses both of which were

unrelated, together with a further, as yet, not fully explained frequency deviation. However, as discussed previously, initial analysis undertaken by National Grid indicates that following the utilisation of all frequency response capability, the further frequency deviation to 48.795Hz could have resulted from a further combined loss of generation of around 250MW or more.

**FIGURE 4**



- 4.3.2 The first loss (Generator A, 345MW generation at 11:34am) resulted in the frequency falling by 0.127Hz. National Grid's operational policy would require for a loss of this magnitude that the frequency deviation is <0.5Hz.
- 4.3.3 The second loss (Generator B, 1237MW at 11:36am) resulted in the frequency falling by a further 0.67Hz to 49.14Hz. National Grid's operational policy would require for a loss of this magnitude that the frequency deviation is <0.8 Hz.
- 4.3.4 The combined effect of 1582MW loss exceeds the maximum secured loss under the security standards which on this day was Generator B which was 1237MW. The maximum loss that National Grid are currently required to secure to is up to 1320MW.
- 4.3.5 For both generation losses, the frequency deviation was wholly commensurate with the size of the generation loss encountered. However, the loss experienced on the 27<sup>th</sup> May resulted from two individual events occurring in very close proximity such as to make them, in effect, a "single" loss which totalled some 1582MW.
- 4.3.6 In summary, for each individual loss of generation, the initial system frequency response worked well, and as such, given the near coincidence of both losses, the system frequency fall down to 49.14Hz was better than expectations.

- 4.3.7 Some two minutes after the loss of Generator B an, as yet not fully unexplained event, resulted in a further fall of frequency to 48.795Hz which initiated the operation of the automatic low frequency demand disconnection relays.

#### **4.4 Automatic Demand Disconnection and Frequency Recovery**

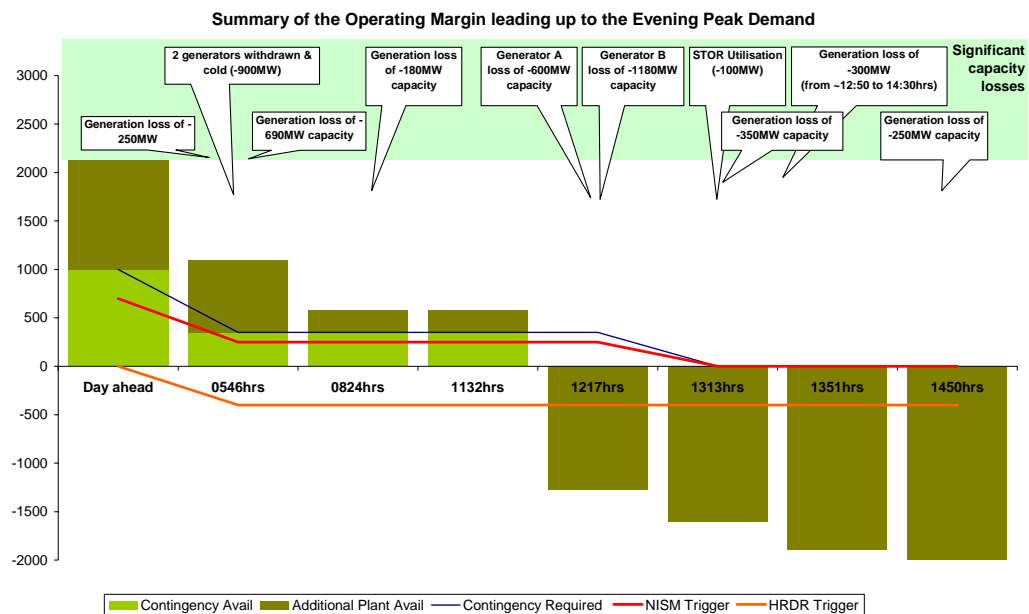
- 4.4.1 The collapse of frequency to 48.795Hz was successfully arrested by the operation of the first stage of automatic low frequency demand tripping relays. Operation of the relays, supported by fast responding generation that had been instructed following the loss of Generator A and then Generator B, together with Open Cycle Gas Turbine generation starting automatically resulted in the frequency recovering towards 50Hz. The frequency returned within Statutory limits within 9 minutes.
- 4.4.2 The Grid Code CC.A.5.5.1(a) stipulates that the first tranche of approximately 5% of demand at each DNO within England and Wales should trip automatically by low frequency relays set at 48.8Hz. With the national demand observed on the day, some 1700MW of demand might have been expected to trip when the frequency fell below 48.8Hz.
- 4.4.3 Initial information obtained from the DNOs suggests some 581MW of demand as having been automatically disconnected. Whilst this is good in terms of minimising supply disruption it does infer that all low frequency relays did not operate. Further information on the effectiveness of the operation of low frequency relays has been requested from the DNOs to understand whether they operated in line with expectations.

#### **4.5 Recovery to Normal Operating Conditions**

- 4.5.1 Within 2 minutes of the operation of the automatic low frequency relays, the ENCC control engineers had instructed a first stage ~5% of manual demand control across 9 DNOs areas. Demand control under Grid Code OC6.5.3(b) should typically be delivered within 5-10 minutes of instruction by National Grid. DNOs have indicated that generally the first ~10% of instructed demand reduction would normally be achieved by voltage reduction.
- 4.5.2 Seven DNOs were instructed under the Grid Code to provide one stage (5%, ~1200MW) of demand reduction.
- 4.5.3 The DNOs initially selected were primarily in the southern part of the network as their demand relief would assist with the balancing of the Transmission network following, most significantly, the loss of 1237MW of generation in the south of the network. The Scottish DNOs were not instructed to provide demand relief as all available generation was committed in Scotland and at that time, there was no further capacity available on the circuits across the Scottish borders to provide increased transfers that would result from a reduction in Scottish demand.

- 4.5.4 Following any major generation loss, the priority for the control engineers is to re-establish the capability of synchronised generation to provide frequency response capability to protect the wider GB system from the impact of any further demand or generation perturbations. On the 27<sup>th</sup> May, frequency response holding to re-secure to the next largest loss on the system was achieved within 15 minutes of the exceptional generation loss.
- 4.5.5 Within 40 minutes of the operation of the automatic low frequency relays instructions were given to all affected DNOs to restore automatically disconnected demand.

**FIGURE 5**



- 4.5.6 Figure 5 summarises the operating margins outlook for the evening demand peak up to and following the loss of Generator A and Generator B (total 1582MW). The resultant impact on operating margins triggered the requirement for a High Risk of Demand Reduction (HRDR) warning to be issued to the market, although demand control had already been instructed.
- 4.5.7 The HRDR was issued at 12:30pm, once the immediate restoration activities were complete and the short to medium term operational impact of the exceptional loss had been assessed.
- 4.5.8 In response to the substantial loss of generation, a number of actions were initiated by the ENCC to procure additional generation in order to quickly restore normal operating conditions for the remainder of the day.
- 4.5.9 Initially, ENCC instructed the generating unit (previously retained on hot standby) to synchronise by 12:59pm.

- 4.5.10 Between 11:52am and 12:01am, ENCC contacted generator EMC's querying the possibility of running their long notice generating plant (typically at 6 to 12hrs notice). ENCC were advised that there were 3 machines (some 1700MW capacity in total) that might be available to generate in some 4-5 hours. Other generation was confirmed as being on at least 6 hours notice to synchronise, with very slow run up rates and therefore would not be able to provide assistance for the evening peak.
- 4.5.11 As a result, these three generating units were given instructions to get them to a hot standby state with a view to synchronise at least 2 machines for the evening peak.
- 4.5.12 A number of further significant generation losses totalling some 700MW (some of which recovered) were incurred during the afternoon.
- 4.5.13 By 3:48pm one of the long notice generating units informed ENCC that they had managed to get their machine ready to synchronise sooner than anticipated and at 3:48pm an instruction was given to them to synchronise at 4:17pm. The remaining two sets would only be able to synchronise by the evening demand peak (after which time the demand would start decreasing). As falling demand levels would substantially resolve the generation deficit, only one of these machines would be required. As a result, the machine with faster run up rates (double those of the third generator) was instructed at 4:01pm to synchronise at 5:01pm. Instructing the third set to synchronise at this time would not have had any impact on the time that demand control was in force.
- 4.5.14 All generators that would be able to assist with the recovery and the evening peak demand were instructed to generate.
- 4.5.15 Early in the afternoon, the ENCC requested the return of two transmission circuits which were out of service for routine maintenance. Neither circuit was actively constraining generation, however, given the uncertainty of the plant position for the rest of the day, the return of these circuits would improve operational flexibility.
- 4.5.16 As the demand fell during the afternoon and more generation came on line, the level of demand control was reduced by instructing DNOs to restore demand. Demand control was distributed across the DNOs, and where possible DNOs were stood down. In addition ENCC sought to limit the time that demand control was applied to any one DNO. By the evening, changed generation patterns meant that location was no longer critical, hence demand control could be applied to two northern DNOs enabling two others to be stood down earlier than would otherwise be possible.
- 4.5.17 Demand Control was in force from 11:40am to 6:05pm and High Risk of Demand Reduction Warning in force from 12:30pm to 7:00pm.
- 4.5.18 Across the early evening peak (at 6:00pm) demand control was only in force across 4 DNOs. All demand control was lifted by 6:07pm.

- 4.5.19 The dual challenges of both the major system disturbance which led to demand disconnection and the extraordinary pattern of generation losses experienced on the 27<sup>th</sup> May provided significant system control challenges. Whilst detailed work continues, it is clear that the ENCC control engineers professionally managed the challenges presented.

## **5 Preliminary Findings and Interim Conclusions**

### **5.1 Performance of Transmission Contracted Generation Plant**

***The overall performance of Transmission contracted generation plant was generally good and in line with our expectations and standards.***

- 5.1.1 This section reports on the performance of Transmission contracted generation plant operating in both Frequency Sensitive Mode (FSM) and Limited Frequency Sensitive Mode (LFSM) during the incident as well as low frequency triggered Open Cycle Gas Turbine plant.
- 5.1.2 In addition to commercial provision of response services (such as large industrial providers), twelve generating units were instructed to operate in FSM and provide frequency response service. Nine of these units appear to have delivered their MW output response in line with expectations. However, for the remaining three units, there appears to have been a combined shortfall of about 60MW to 80MW. This is currently subject to detailed analysis and is being pursued with the relevant generators.
- 5.1.3 The above response shortfall appears to have been compensated by an unexpected and significant response delivered from a generating unit that had not been instructed to operate in FSM.
- 5.1.4 The number of generating units operating in LFSM is large and an assessment of their MW output performance against Grid Code Connection Condition CC.6.3.3 is being carried out. The initial observation based on inspection of actual MW output indicates that the vast majority appear to have operated in line with expectation but there might have been minor shortfalls on a few units. However, the net effect across all generation shows better MW response than Grid Code CC6.3.3 overall. The specific performance of individual generating units over the 15 minute period around the low frequency demand disconnection is under investigation.
- 5.1.5 A number of Open Cycle Gas Turbines are set to operate by low frequency relays (set at 49.5Hz and 49.6Hz) and should have reached full MW output (567MW) in 5 minutes i.e. at approximately 11:41am or around 5 minutes after the loss of Generator B. Initial analysis suggests that there were some shortfalls in output and under performance will be pursued with the relevant generators.

## 5.2 Performance of Embedded Generation Plant

***The overall performance of Embedded generation plant is unclear and further information has been requested from the DNOs.***

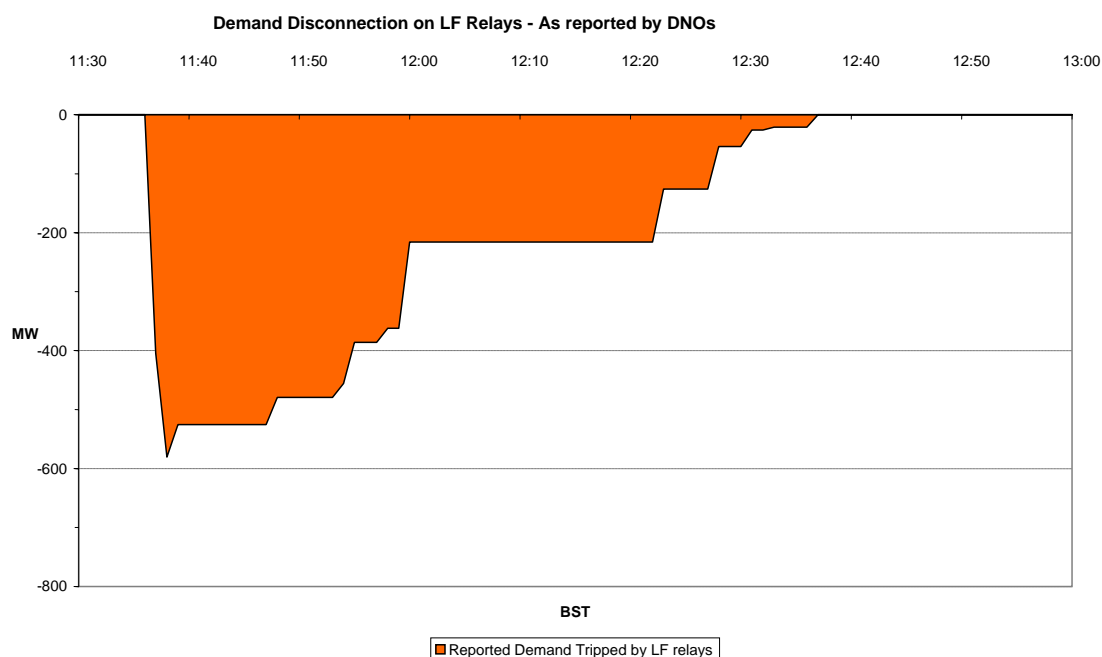
- 5.2.1 Under the auspices of the GB Grid Code Review Panel, a reporting procedure was established in 1997 where the DNOs are required to provide National Grid with information on embedded generation that may have tripped in the event of a significant incident on the GB Transmission system including generation trips causing large frequency deviations.
- 5.2.2 Initial information obtained from the DNOs indicates that some embedded generation plant did trip during the 27<sup>th</sup> May incident. The information received from DNOs to date, indicates that the known amount of embedded generation loss is approximately 250MW but there is still thought to be some further trips at small power stations, the scale of which is still under investigation. This information has been requested from the DNOs.

## 5.3 Performance of National Low Frequency Demand Disconnection Scheme and Associated Low Frequency Relays

***The overall performance of the LFDD scheme is unclear and further information has been requested from the DNOs.***

- 5.3.1 The low frequency relays used by the National Low Frequency Demand Disconnection scheme are set to enable the automatic disconnection of demand uniformly in distribution networks generally in 9 blocks. The first demand block is set, on average, at 5% in each DNO area in England & Wales and the relays are set to trip at 48.8Hz. This is summarised in Appendix 1.

**FIGURE 6**





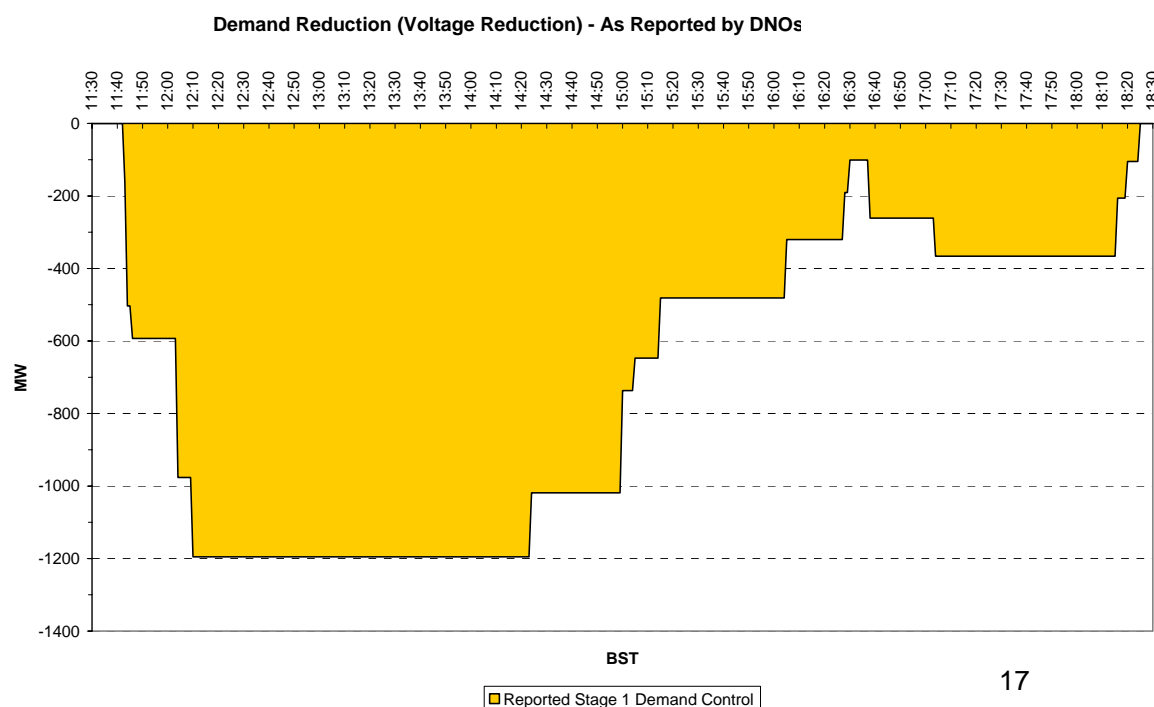
- 5.3.2 The minimum system frequency during the incident was 48.795Hz and was below 48.8Hz for 1.22 seconds. As indicated in Figure 6 above, the actual amount of demand disconnected by low frequency relays, as initially reported by the DNOs, is around 581MW whereas the 5% block requirement would suggest that around 1700MW might have been disconnected.
- 5.3.3 The disconnection of around 581MW appears to have been just sufficient to arrest the fall in frequency and to cause a slight upward recovery.
- 5.3.4 It is possible that some relays did not operate. This may be due to a variety of reasons such as incorrect relay setting, relay design tolerances, quality of measured frequency signal etc. Detailed information on relay performance is currently being sought from the DNOs.
- 5.3.5 It is noted that whilst only around 581MW of demand was disconnected, this resulted in much less supply disruption to customers nationwide. A larger amount of disconnection would have resulted in a greater supply disruption but a faster recovery of system frequency towards 50Hz.

#### 5.4 Performance of Demand Control by Voltage Reduction

***The performance of Demand Control by Voltage reduction appears to be generally in line with expectations although further information has been requested from the DNOs***

- 5.4.1 Within 2 minutes of the operation of low frequency relays, and in accordance with the Grid Code OC.6.5, Demand Control instructions were given to 9 DNOs estimated at around 1200MW of manual demand reduction by voltage reduction. Figure 7 summarises the demand reduction delivered as reported by the DNOs in their initial returns.

**FIGURE 7**



5.4.2 Together with other actions discussed in section 4.5, the instructed Demand Control enabled:

- a) the re-establishment of the already exhausted frequency response holding on Frequency Sensitive mode generation plant in less than 15 minutes, and
- b) quicker restoration of the demand disconnected by low frequency relay operation. All instructions to affected DNOs to restore disconnected demand were completed by ENCC within 40 minutes of the automatic demand disconnection. (Initial returns from the DNOs indicate that all customer supplies were restored within 23 minutes of receipt of this instruction).

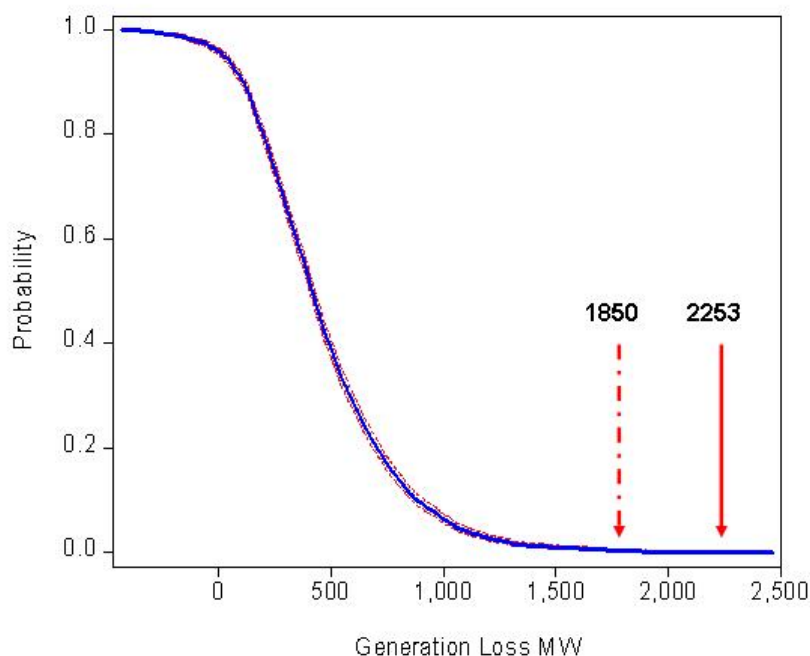
5.4.3 Specific information on the various aspects of the Demand Control instructions implemented by the DNOs is currently being sought from them to help with the complete analysis of this event.

## 5.5 System Operational Margins and Frequency Excursion

5.5.1 The application of the reserve policy as described in section 3.1.11 above is that for the period from Gate closure (about 1.5hrs ahead) to real time we would cover a cumulative plant loss of up to 1850MW. In the event, from gate closure to real time generation losses totalled 2253MW. This is illustrated in Figure 8 below:

**FIGURE 8**

**Probability of Generation Loss between Gate Closure and Real Time**

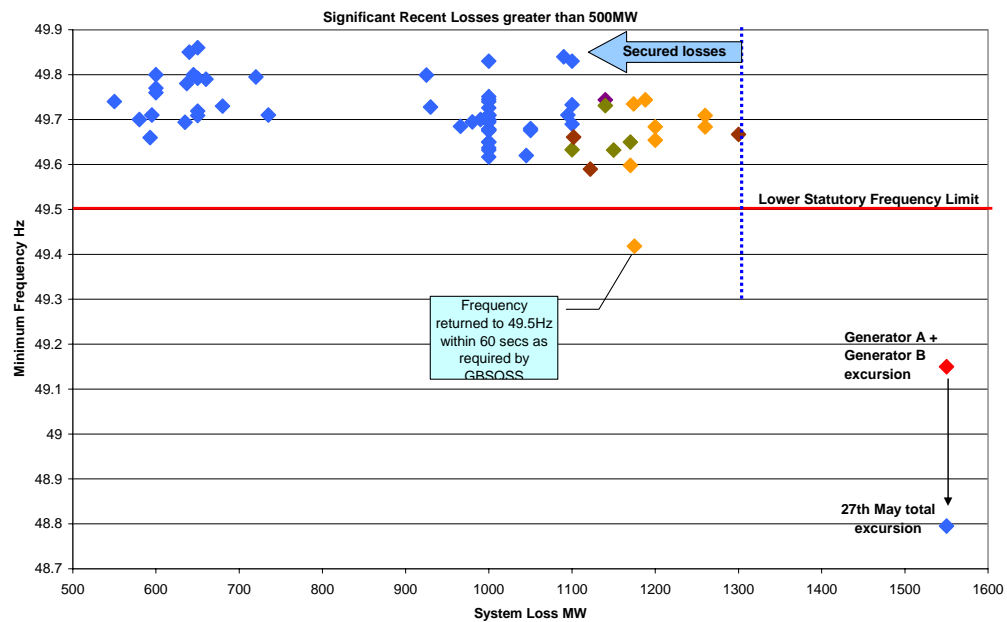


5.5.2 The level of generation capacity loss experienced (2253MW) is a level that would only be experienced once in every 4 to 5 years. As a result

of the exceptional generation loss, the use of demand control for the afternoon period is as would be anticipated by the operating standards.

- 5.5.3 There have only been two reportable frequency deviations since 1989/90. The first on 17<sup>th</sup> November 1995, when the frequency fell to 49.184Hz for 3 min 40 sec for a 1280MW generation loss and the second on 19<sup>th</sup> February 1996, when the frequency fell to 49.038Hz for 3 min 20 sec for a 1000MW generation loss. The Generator A and Generator B loss and associated frequency excursion is compared to historical events across the last 10 years of significant plant loss in Figure 9 below.

**FIGURE 9**



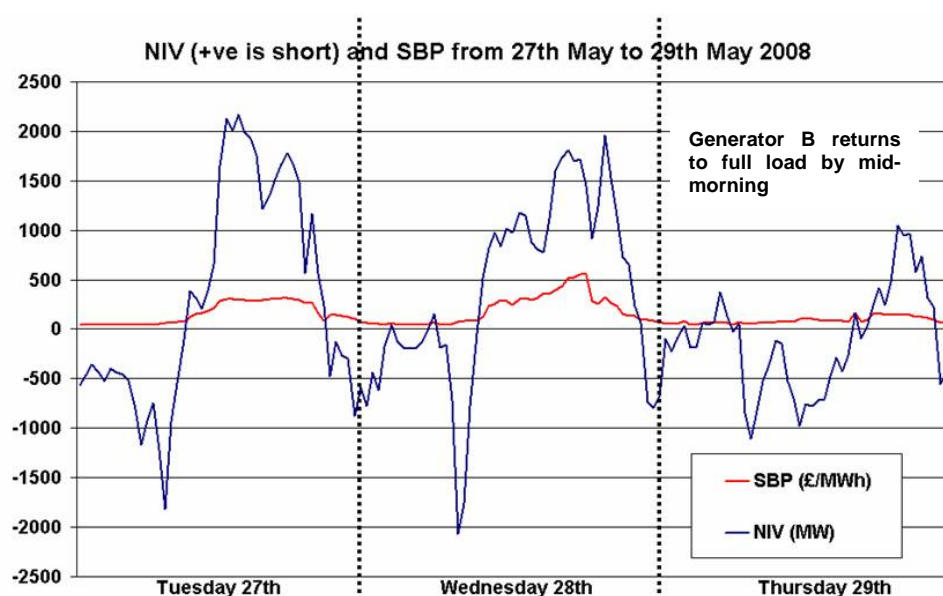
- 5.5.4 This was the largest “single” loss of generation for in excess of 10 years. The frequency excursions that resulted from the initial Generator A and subsequent Generator B generation losses are as we would expect. However, as noted further data and analysis is required to fully explain the subsequent frequency deviation that resulted in the triggering of the LF automatic demand tripping.
- 5.5.5 The subsequent plant shortages and demand control required throughout the afternoon are consistent with the impact of such a large loss in the context of our operating margins which statistically require demand control in such extreme conditions.
- 5.5.6 It is noted that the generation loss encountered as a result of the Generator A and Generator B failures was the largest generation loss since 1998 (when detailed electronic database information became available). When compared to those losses and the resultant frequency deviation, performance for those secured losses supports the current levels of frequency response on the system.

## 5.6 Communications with Market, Generators and Distribution Network Operators

- 5.6.1 All warnings required by market rules were issued as required under the Grid Code. Messages were issued by fax and placed on the Balancing Mechanism Reporting System (BMRS) website.
- 5.6.2 National Grid believes that effective communications with the Generators and DNOs were maintained throughout the day and that the whole industry worked well together to support the restoration of consumers off supply and orderly return to normal operating conditions.

## 5.7 Market Response

**FIGURE 10**



- 5.7.1 Figure 10 summarises the market position for the 27<sup>th</sup>, 28<sup>th</sup> and 29<sup>th</sup> May.
- 5.7.2 After the losses on the morning of the 27th May, the notice times for a number of oil generators were reduced following a request from National Grid. However, there is limited evidence of the market covering its short position across the day and National Grid synchronised all feasible plant to help meet demand.
- 5.7.3 The following day, the system is still short indicating that market participants have not fully covered their positions. Generator B starts to resynchronise late on the 28th May and returns to full load mid morning of the 29th May. This significantly improves the system balance.

## **6 Further Work In Progress**

### **6.1 Performance of Transmission Contracted Generation Plant**

- 6.1.1 The generating units that exhibited a shortfall in MW output in response to frequency changes are being investigated with the relevant Generators in order to ensure adequate response delivery under large frequency deviations in accordance with the Grid Code and Ancillary Service Contract requirements.

### **6.2 Performance of Embedded Generation Plant**

- 6.2.1 Additional detailed information has been requested from the DNOs to establish the precise amount, timing and trip mechanism of all embedded generation that tripped during the incident including small scale generation. National Grid considers that this information is vital to explaining the full facts of this incident and in particular, the fast collapse from 49.14Hz towards 48.795Hz that began around 11:37am and led to the automatic disconnection of demand by low frequency relays.

### **6.3 Performance of Low Frequency Demand Disconnection Scheme and Associated Low Frequency Relays**

- 6.3.1 Additional detailed information is being sought from the DNOs on the demand disconnected by the Low Frequency Demand Disconnection scheme as well as on the performance of the low frequency relays employed by each DNO in England and Wales. The latter will include information on any relays that may have failed to operate and the reasons for this.

### **6.4 Demand Control by Distribution Network Operators**

- 6.4.1 Additional detailed information on the Demand Control implemented by the DNOs has been requested. This includes the level of demand control the DNOs tried to implement, the specific actions taken and their timings as well as the level of demand reduction achieved.

### **6.5 Progress of Issues Raised by this Event**

- 6.5.1 Such a rare event will inevitably provide a number of learning points. National Grid's investigation on these issues will continue in conjunction with relevant industry bodies. In particular we expect actions arising from the events of the 27<sup>th</sup> May to be taken forward through the Energy Emergencies Executive Committee (E3C) and the Grid Code Review Panel (GCRP).

## **7 Appendices**

## Appendix 1

### Grid Code Low Frequency Demand Disconnection (LFDD) Scheme

The table below is extracted from the Grid Code Connection Conditions showing the LFDD scheme settings in Great Britain.

| Frequency Hz   | %Demand disconnection for each <b>Network Operator</b> in <b>Transmission Area</b> |     |       |
|----------------|--|-----|-------|
|                | NGET   | SPT | SHETL |
| 48.8           | 5  |     |       |
| 48.75          | 5  |     |       |
| 48.7           | 10   |     |       |
| 48.6           | 7.5  |     | 10    |
| 48.5           | 7.5  | 10  |       |
| 48.4           | 7.5  | 10  | 10    |
| 48.3           |  |     |       |
| 48.2           | 7.5  | 10  | 10    |
| 48.0           | 5  | 10  | 10    |
| 47.8           | 5  |     |       |
| Total % Demand | 60   | 40  | 40    |

Note – the percentages in table above are cumulative such that, for example, should the frequency fall to 48.6 Hz in the **NGET Transmission Area**, 27.5% of the total **Demand** connected to the **GB Transmission System** in the **NGET Transmission Area** shall be disconnected by the action of **Low Frequency Relays**.

## Appendix 2

### Hyperlink references used in this report

GB SQSS (Page 5)

[http://www.nationalgrid.com/NR/rdonlyres/FBB211AF-D4AA-45D0-9224-7BB87DE366C1/15460/GB\\_SQSS\\_V1.pdf](http://www.nationalgrid.com/NR/rdonlyres/FBB211AF-D4AA-45D0-9224-7BB87DE366C1/15460/GB_SQSS_V1.pdf)

Balancing Principles Statement (BPS) (Page 7)

<http://www.nationalgrid.com/NR/rdonlyres/03A5FB8B-D6B9-450A-AB7D-11021233BB30/24545/BPSv80effectivefrom1apr08.pdf>

Reserve presentation (Page 7)

[http://www.nationalgrid.com/NR/rdonlyres/012BE506-F6A1-4D16-BADD-C7A2FC49C52D/1913/NGTs\\_Role\\_in\\_Securing\\_Reserve.pdf](http://www.nationalgrid.com/NR/rdonlyres/012BE506-F6A1-4D16-BADD-C7A2FC49C52D/1913/NGTs_Role_in_Securing_Reserve.pdf)