National Grid Transco

NATIONAL GRID COMPANY PLC

(A wholly owned subsidiary of National Grid Transco plc)

Investigation Report into the Loss of Supply Incident affecting parts of the West Midlands at 10:10 on the morning of Friday, 5 September 2003

This report has been produced by National Grid Company plc (National Grid) to record the investigation findings concerning the loss of supply in the West Midlands on 5 September 2003. The purpose of the investigation is to enable National Grid to identify 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 in it have not been compiled in accordance with rules of evidence and cannot be treated as determining either National Grid's or any individual's legal liability.

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Investigation Report into the Loss of Supply Incident affecting parts of the West Midlands at 10:10 on Friday, 5 September 2003.

Executive Summary

Introduction

1 A combination of events led to an electricity power supply failure in the West Midlands, at 10:10 on the morning of 5 September. Restoration of demand began at 10:21 and power supplies from National Grid were fully restored by 10:52. This report describes the circumstances leading to the loss of supply, the steps taken to restore supplies and the measures currently being progressed to minimise the risk of a recurrence.

Hams Hall Substations

2 The Hams Hall site contains three substations operating at 400kV, 275kV and 132kV, as shown in figure 1 overleaf. The substations are close to each other and are owned by National Grid. Normal demands of around 250MW for this time of year are drawn by two distribution network operators (DNOs), Aquila and East Midlands Electricity, to supply domestic customers and large users. As a result of the incident, all supplies were lost from Hams Hall.

Construction/Commissioning Activity in the Substations

3 Currently, National Grid is undertaking a significant investment in the West Midlands network to manage current and expected changes in the energy market and demand growth in the West Midlands area. This programme is being undertaken in conjunction with the replacement of ageing assets in an efficient, co-ordinated and economical manner. One of the key components of this West Midlands Strategy is a major construction and asset replacement programme being undertaken at the Hams Hall site.

4 The work at Hams Hall is part of a five year programme due to complete in 2005, and encompasses all three substations on the site. This will enable the future decommissioning of the 275kV substation, leaving the 400kV and 132kV substations being interconnected by 4 x 240MVA supergrid transformers (SGT6, 7, 8 and 9). The works include the addition of two new 400/132kV transformers, and the removal of the three existing 275/132kV transformers (SGT1, 2 and 3), which are close to the end of their lives. There will be a significant extension to the 400kV substation, and reconfiguration of connections between the 400kV and 132kV substations. The final phase of this stage of the works will be the complete rebuilding, in sections, of the 132kV substation.

5 On the evening prior to the fault (4 September) the existing supergrid transformer SGT6 circuit had been re-commissioned after the transfer of primary connections and changes to its control circuitry. As part of the ongoing construction work, SGT1 and SGT2 had been taken out of service, on the morning of the incident (5 September). SGT8 was a new transformer that had been in service for approximately 3 weeks, while SGT7 and SGT9 were still undergoing construction works, and were not in service.

6 In line with normal practice, the arrangement of the transmission system to accommodate the construction and commissioning programme had been agreed well in advance with both of the operators of the distribution system for the West Midlands region, Aquila and East Midlands Electricity.

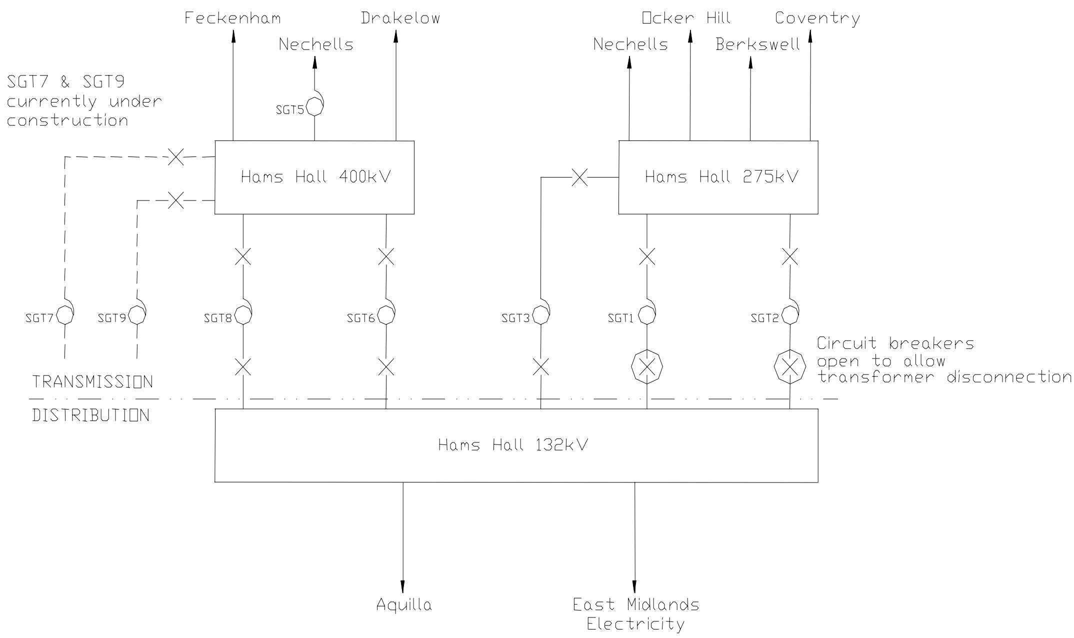

Figure 1 : Diagram of the transmission system at Hams Hall prior to the fault

Request to Remove Circuit from Service

7 On the morning of 5 September, during a site check of the most recently re-commissioned circuit, site staff detected a burning smell in the 400kV relay room of SGT6. At 10:03, engineers at Electricity National Control Centre (National Control) were told by the commissioning team at Hams Hall that the SGT6 circuit may have a problem. Control staff started to consider bringing SGT1 and SGT2 back in to service in the event that SGT6 had to be removed from service.

8 Subsequently, smoke and sparks were observed in a relay panel in the SGT6 relay room and site staff asked National Control to take the circuit out of service as quickly as possible, so that they could investigate the problem. The engineers at National

Control confirmed that the system was still secure with the remaining transformers, and given the urgency of the request, and of the prospect of SGT1 and SGT2 coming back into service, confirmed that SGT6 should be taken out of service.

9 The SGT6 low voltage circuit breaker was opened at 10:09, taking the transformer off load. This enabled a safe shutdown of the transformer and the investigation into the burning in the relay panel to commence. This resulted in Hams Hall 132kV substation being supplied from one transformer on the 400kV substation, SGT8, and one transformer on the 275kV substation, SGT3.

The Subsequent Fault

10 Less than half a minute after SGT6 was taken out of service, the automatic protection equipment on SGT8 activated unexpectedly, taking one of the remaining transformer circuits supplying the 132kV substation off load.

11 Following the disconnection of SGT8, the demand of 253MW at Hams Hall 132kV substation was supplied only from the 275kV substation via SGT3, the one remaining 120MVA transformer. The automatic protection on this remaining transformer operated correctly, to prevent the transformer from being overloaded. This disconnected all load at Hams Hall 132kV substation from the transmission system, causing the loss of supply. Approximately 250MW of supplies were lost, affecting over 200,000 of Aquila's and East Midlands Electricity's customers, as well as larger users, including Birmingham International Airport and the National Exhibition Centre (who were both able to minimise the impact by use of their back up supplies).

Restoration

12 The restoration process began at 10:11, with Aquila being requested to split its demand taken from Hams Hall into smaller blocks. The Hams Hall 132kV substation was then re-energised via the SGT3 circuit from the 275kV substation and the first block of demand restored at 10:21.

13 Following prompt action from the commissioning engineers the SGT6 circuit was restored to load at 10:36, followed by the recall of SGT2 to service at 10:48. By 10:52 all supplies from the 132kV substation had been restored.

14 During the incident there was substantial operational communication between National Grid, Aquila and East Midlands Electricity. Communications were initiated at 10:10, following the loss of supplies at Hams Hall.

15 In the wider communication exercise during the day, in addition to briefing the media, National Grid invoked its incident procedures and was in contact with DTI, Ofgem, energywatch and the affected electricity distribution companies.

Investigation and Findings

16 An urgent investigation was instigated with a view to understanding the causes of the incident and taking effective actions to minimise the risk of a recurrence.

Findings

17 The investigation had found that the initial problem on SGT6 was caused by wiring changes made incorrectly during installation of a new substation control system. Rigorous adherence to the established procedures for design changes, installation and testing would have prevented this.

18 However, the problem on SGT6 was not, in itself, the cause of the loss of supply.

19 The subsequent loss of SGT8 resulted from the incorrect operation of a protection relay. The instructions for setting this newly commissioned multi-function relay were unclear and therefore misinterpreted. In addition, the currently specified tests for protection relays need to fully recognise the complexity of these new multi-function relays. In particular, they need to ensure that any unwanted functions have been properly disabled prior to the relay being placed in service.

20 The loss of SGT3, which caused the ultimate loss of supply, was through correct operation of the transformer's protection, since the transformer was overloaded.

Actions and Recommendations

21 **All commissioning works at Hams Hall were suspended by the investigation team until assurance had been given that the cause of the incident was understood and remedial works had been completed to prevent a recurrence.**

22 **An urgent design review was instigated and completed on 11 September, to ensure the findings of the investigation, relating to transformer protection schemes, had been applied to all relevant assets at Hams Hall.**

23 **An urgent survey was carried out of all in-service multi-function relays, of the type found at Hams Hall, employed on the tripping of supergrid transformers. No similar risks of inadvertent tripping resulting from unwanted relay functionality were discovered.**

24 **A series of generic recommendations has been made to improve and reinforce the application of the necessary processes and procedures on all relevant future commissioning works. These generic recommendations will be taken forward, on an urgent basis, under the general review of National Grid's management of protection systems, which was recommended in the South London investigation report.**

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Investigation Report into the Loss of Supply Incident affecting parts of the West Midlands at 10:10 on Friday, 5 September 2003

Introduction

25 National Grid Company plc (National Grid), a wholly owned subsidiary of National Grid Transco plc, transports electricity and balances supply and demand on a second-by-second basis. National Grid delivers electricity from generators and interconnectors to 12 distribution network operators for local distribution to over 24 million consumers and directly to a small number of large industrial users. National Grid is the sole holder of an electricity transmission licence for England and Wales and has a statutory duty under the Electricity Act 1989 (as amended by the Utilities Act 2000) to develop and maintain an efficient, co-ordinated and economical system of electricity transmission and to facilitate competition in the supply and generation of electricity.

26 On 5 September 2003 a combination of events occurred during the construction of an extension to a National Grid substation at Hams Hall in the West Midlands, resulting in an electricity supply failure from 10:10, with the first supplies being restored by 10:21 and full supplies restored by 10:52.

27 At the time of the incident Hams Hall was supplying some 253MW of demand, to two distribution network operators (DNOs), Aquila and East Midlands Electricity. The demand drawn from Hams Hall supplies domestic customers in Tamworth, Solihull, the conurbation of southeast Birmingham and large users.

28 The loss of supply affected around 58,000 customers supplied from the East Midlands Electricity network and around 143,000 customers supplied from the Aquila network. All supplies from the transmission system to Aquila and East Midlands Electricity were restored within 38 minutes.

29 Roger Urwin, National Grid Transco's Chief Executive Officer initiated an Incident Investigation led by Nick Winser, Group Director Transmission and Chief Executive of National Grid Company plc.

30 This is the outcome of the incident investigation into the events of the 5 September 2003.

Background

31 The National Grid transmission system provides an integrated network for the bulk transfer of power across England and Wales. The transmission system, which is operated at 400,000 volts and 275,000 volts (400kV and 275kV), connects major power stations and supplies electricity to the regional distribution networks. The transmission system has been designed and built to be robust and durable, with the various types of assets having an expected life of between 15 years and 80 years.

32 Since 1990, around £3,600m has been invested in the National Grid transmission system. Of this, approximately £250m has been invested in the West Midlands area.

33 The transmission system in the West Midlands facilitates the transmission of power from remote generating stations into Birmingham, and is also part of a wider network facilitating the bulk transfer of power around the country.

34 The West Midlands transmission network is shown in figure 2. The network is made up of substations, which include switchgear, transformers, compensation plant and protection and control equipment. 400kV and 275kV circuits comprising both overhead lines and underground cables connect these substations.

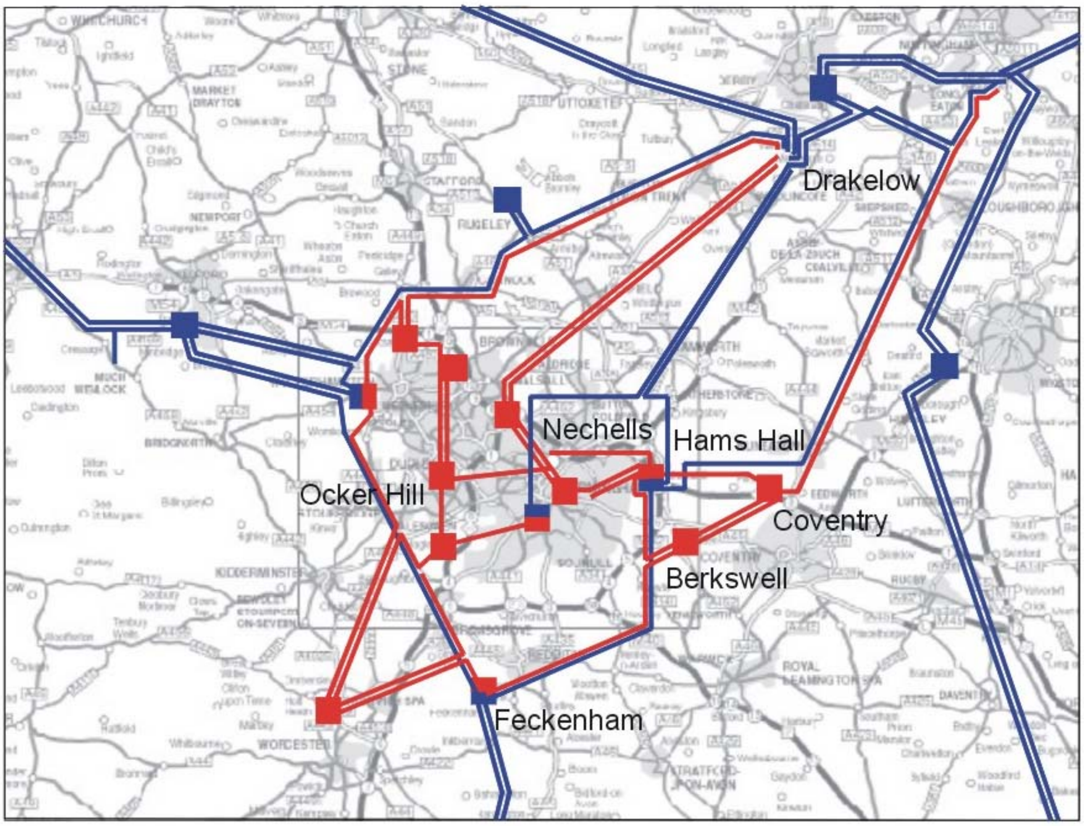


Figure 2 : Existing Transmission system in the West Midlands

35 Currently, National Grid is undertaking a significant investment in the West Midlands network to manage current and expected changes in the disposition of generation, and predicted growth in consumer demand in the West Midlands area. This strategic investment is being undertaken in conjunction with the normal replacement of ageing assets in an efficient, co-ordinated and economical manner. This co-ordinated programme of investment forms National Grid's "West Midlands Strategy", a key component of which is a major construction and asset replacement programme being undertaken at Hams Hall.

36 The Hams Hall site contains three substations at 400kV, 275kV and 132kV. These substations are close to each other and are owned by National Grid. Demands of around 250MW, the normal level for this time of year, are drawn by two independent distribution network operators (DNO's), Aquila and East Midlands Electricity to supply domestic customers and large users including Birmingham International Airport and the National Exhibition Centre. Following the incident, all supplies were lost from Hams Hall.

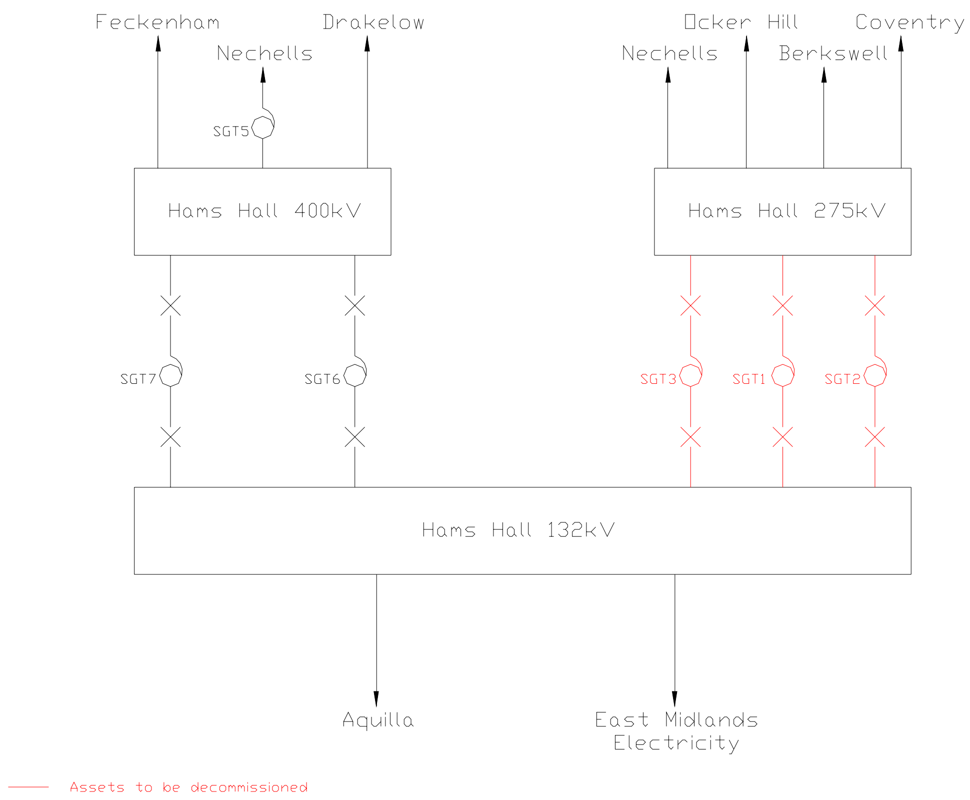


Figure 3 : Hams Hall substation configuration prior to start of works

37 The strategic work at Hams Hall is being carried out at all three substations on the site, over a five year period. Around £45m has been invested so far at Hams Hall and on the adjacent substations and network. The 400kV substation is being extended to

allow additional bays to be added for future 400kV circuits, which will come about by uprating existing 275kV circuits to 400kV, and two new additional 240MVA 400/132kV transformers. The new transformers will provide further supply capacity to the 132kV substation and permit the decommissioning of the existing 120MVA 275/132kV transformers, which are approaching the end of their asset lives. Following the replacement of the 275/132kV transformers with the new transformers fed from the 400kV substation, the whole of the 132kV substation will be rebuilt in stages.

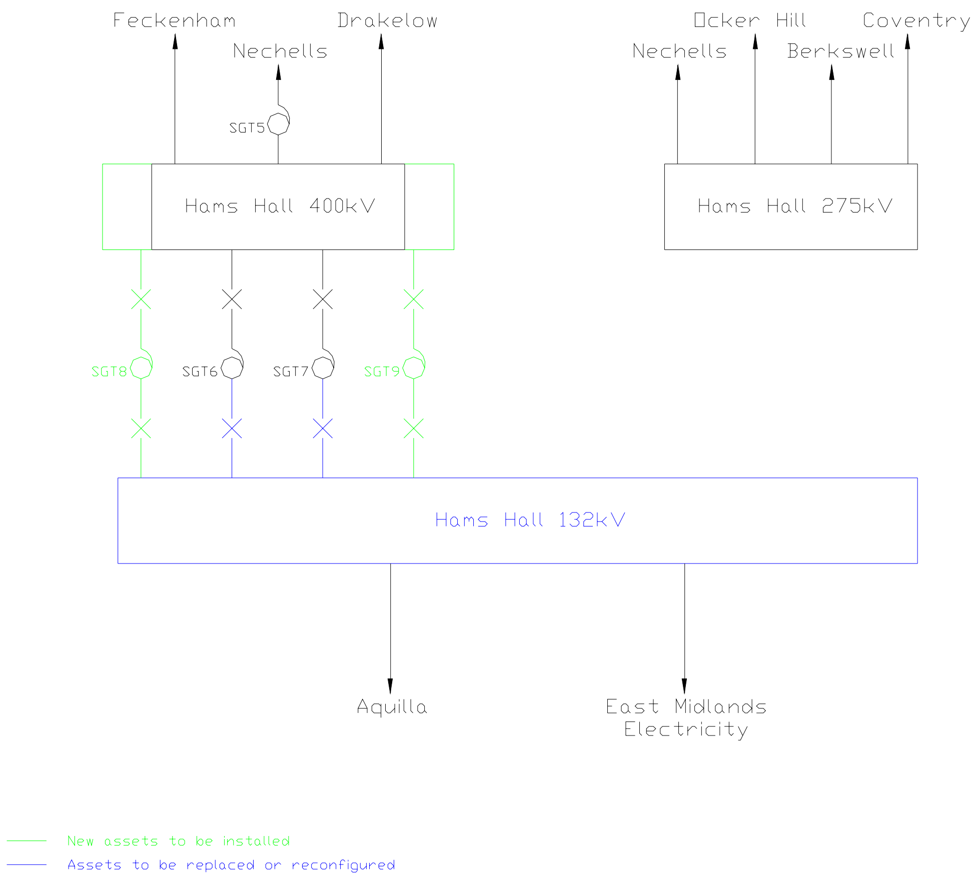


Figure 4 : Configuration of Hams Hall after construction works

38 In later phases of the West Midlands Strategy, the existing 275kV circuits, connected to the 275kV substation, will be uprated to 400kV and transferred across to the 400kV substation. This will facilitate the decommissioning and removal of the whole 275kV substation.

39 Much of National Grid's investment in the West Midlands was carried out over the period 1992 to 1995, as older coal fired generating stations in the area were closed and transmission reinforcement was carried out to enable increased power transfers into the area. A number of supply points to local distribution networks were also reinforced to increase capacity at this time, including Hams Hall and Rugeley. Over the last two years, investment has been around £20m per year, and this investment will continue into the future. This includes further works at Hams Hall to complete the 132kV substation replacement, the installation of additional capacity at other supply

points including Feckenham and Willenhall, and the further installation of reactive compensation equipment.

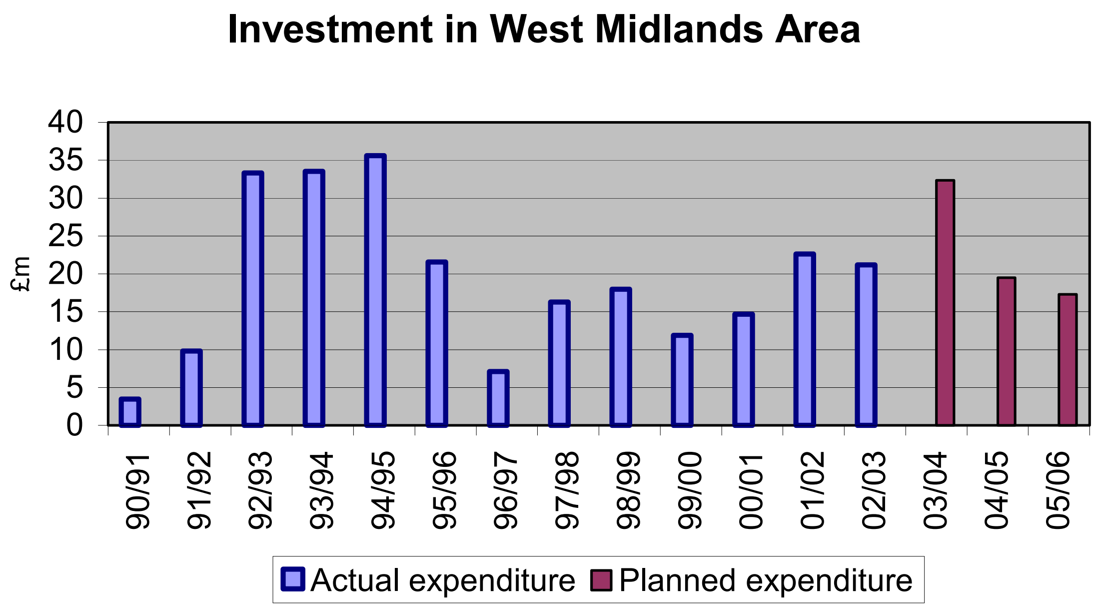


Figure 5 : Investment in the West Midlands area

Operating Arrangements on the Day

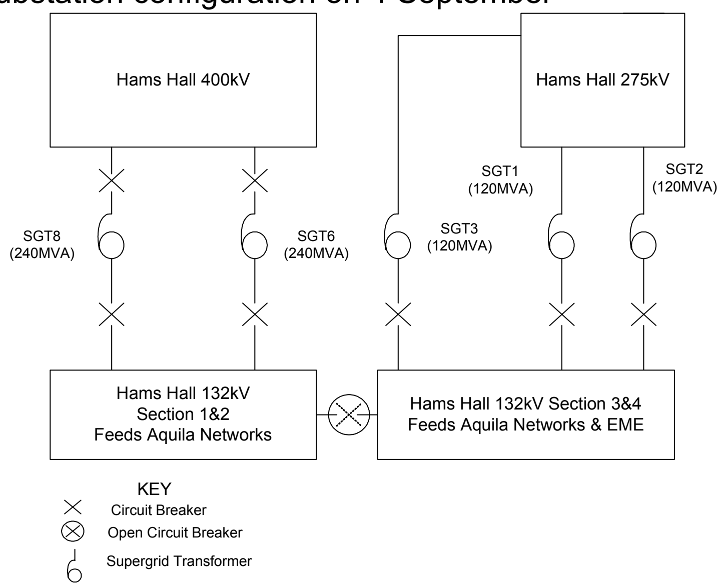
40 On the morning of Friday the 5 September, prior to the incident, the supplies to Hams Hall 132kV substation operating in accordance with the relevant Security and Quality of Supply Standard (SQSS).

41 The transmission system associated with Hams Hall 132kV substation had been configured so that a number of circuits could be out of service for construction work. These are detailed in the table below. These "outages" were part of a complex sequence of outages and commissioning work associated with the Hams Hall part of the West Midlands reinforcement scheme. The outage pattern and system configuration had been closely evaluated to ensure that the required operational standards were met at all times and this process included liaison with the distribution network operators supplied from Hams Hall namely East Midlands Electricity and Aquila.

Circuit	Reason	Dates
Hams Hall 275kV Mesh Corner 3 & SGT2	Outage associated with ongoing construction work. SGT2 to be decommissioned	5 Sept – 10 Oct
Hams Hall 275kV Mesh Corner 4 (part) & SGT1	Outage associated with ongoing construction work. SGT1 to be decommissioned	5 Sept – 9 Sept
Hams Hall 132kV Main Busbar Section 4	Outage to disconnect SGT2 from the 132kV busbars. Associated with ongoing construction work.	5 Sept – 12 Sept

42 The configuration of Hams Hall 132kV substation on the evening of 4 September is shown below. There are five supergrid transformers supplying the 132kV substation. SGT6 and SGT8 take supplies from the 400kV substation and SGT1, 2 and 3 take supplies from the 275kV substation. The 132kV substation is normally configured into two parts to reduce the damage to equipment from the currents that might flow if a fault were to occur.

Figure 6 : Substation configuration on 4 September



43 In accordance with the agreed construction programme, SGT8 had been commissioned on to the system on 17 August 2003, and the existing transformer SGT6 had been re-commissioned on 4 September following changes to its control system and primary connections. The next stage of this programme was to decommission SGT1 and SGT2 to allow work to continue on the construction of SGT7 and SGT9 and associated connections to the 400kV and 132kV substations. Following a series of switching operations, SGT1 and SGT2 were switched out of service at 06:12 that morning. This resulted in the load at Hams Hall 132kV substation being supplied by SGT3, 6 and 8. Because potential fault currents were now lower, the two sections of the 132kV substation were coupled together to increase security of supply. The power flows indicate the situation immediately prior to 10:03.

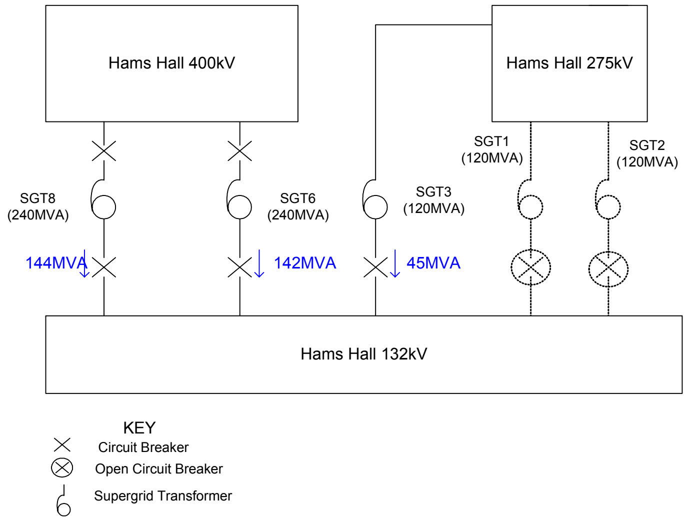


Figure 7 : Substation configuration immediately prior to fault

Sequence Of Events

44 On the morning of 5 September, during a general inspection of the SGT6 relay room by a National Grid engineer, a burning smell was detected. At 10:03 an engineer on site indicated a problem with SGT6 to the Electricity National Control Centre (National Control) at Wokingham.

45 Staff at National Control carried out an assessment, which indicated that it was possible to switch SGT6 out of service without causing overloading of the two remaining supergrid transformers SGT3 and SGT8. Operational Standards of Security require the system to be operated so that transformers can be switched out of service without undue system impact and this was the case in this instance.

46 Enquiries were made to check the status of SGT1 and SGT2 that had been removed from service at 06:12 that morning. The return of these SGTs, whilst not necessary to secure supplies, would give additional capacity to replace SGT6. Safety precautions had only just started for the transformers to be worked on and National Control requested that these works should proceed no further.

47 Further inspections on site of the relay panel associated with SGT6 identified smoke emanating from the base. When charred cables and localised sparking were observed, the engineer contacted the National Grid Control Centre and requested that the SGT6 circuit be removed from service as quickly as possible.

48 The urgency of the situation was such that it would not be possible to restore SGT1 and SGT2 before switching out SGT6. However the decision was still taken to recall SGT1 and SGT2 to service as soon as possible, so that the additional capacity would be available as a contingency.

49 The 132kV circuit breaker of SGT6 was opened at 10:09 to take it off load. The loadings on SGT3 & SGT8 were observed to increase as expected, but remained within the equipment rating, as shown below.

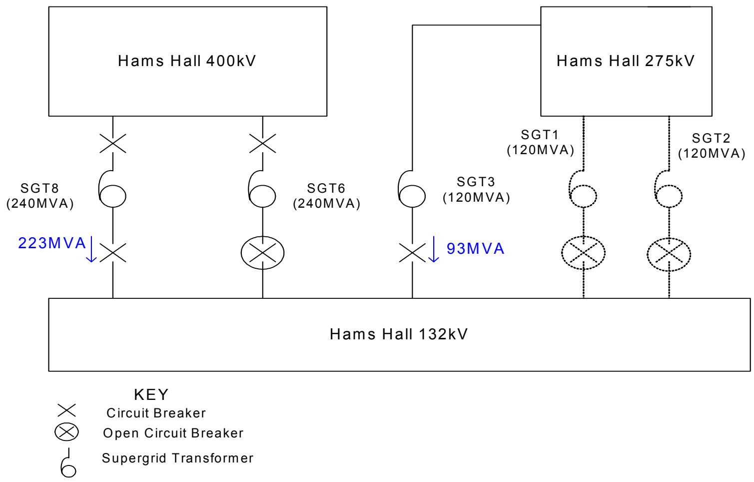


Figure 8 : Substation configuration immediately after disconnection of SGT6

50 Less than 30 seconds later the automatic protection equipment for SGT8 operated unexpectedly, automatically switching the transformer out of service. This resulted in the remaining supergrid transformer, SGT3 carrying the entire Hams Hall 132kV load.

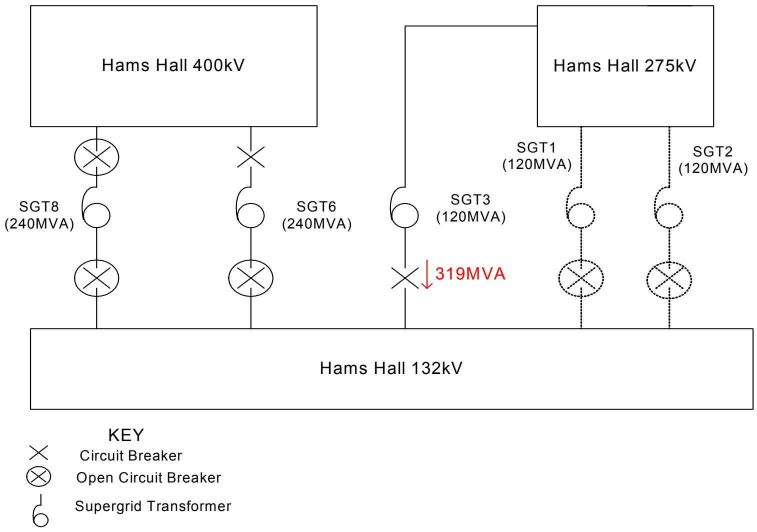


Figure 9 : Substation configuration after disconnection of SGT8

51 The 320MVA of load was in excess of the 120MVA rating of SGT3 and automatic protection correctly operated to disconnect the load, to prevent damage to the transformer. This resulted in supply failure at the Hams Hall 132kV substation.

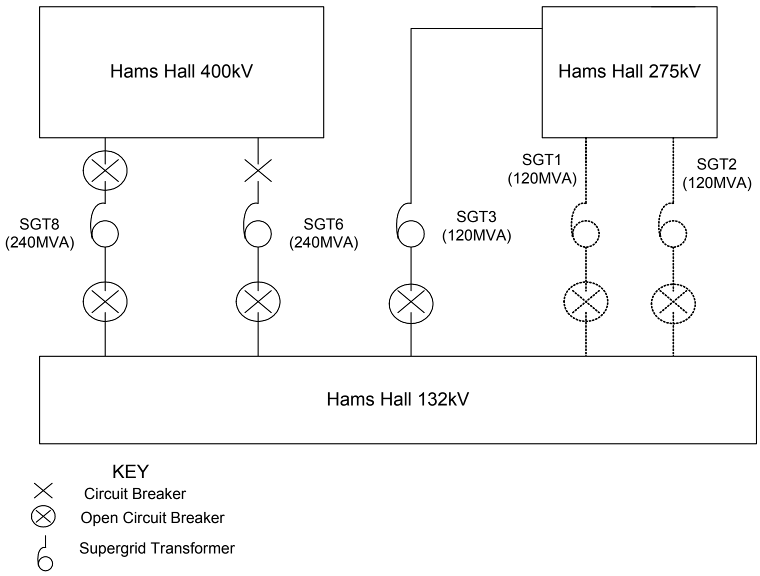


Figure 10 : Substation configuration after disconnection of all transformers

52 National Control made contact with the control rooms of East Midlands Electricity and Aquila at 10.11, informing them of the loss of supply and requesting them to prepare

their networks for supplies to be restored. This process involves segregating the demand into discrete blocks, so that the load being restored can be matched to available transformer capacity in a controlled manner. This would also include an assessment as to whether any of this load could be immediately restored from other nearby grid supply points, via the distribution network operators' own distribution systems.

53 Assessing the alarms received, and after consulting with site staff, National Control concluded that SGT3 could be returned to service immediately, without further investigation, in order to restore some of the supplies. At the same time immediate checks were initiated, on site, to ascertain the reason why SGT8 protection had operated and the reasons for the concerns surrounding the SGT6 circuit.

54 At 10:21 SGT3 was returned to service, making limited supplies available to East Midlands Electricity and Aquila. The first supplies were restored to Aquila at 10:23. By 10:25, supplies to Sutton Coldfield, and the south east Birmingham 132kV network towards Solihull were restored. East Midlands Electricity chose to restore their Tamworth load via an alternative connection to the Drakelow Grid Supply Point and this was complete by 10:25. The limited capacity of SGT3 restricted the amount of load that could be restored. For this reason switching operations were initiated at 10:31 in order to restore SGT2 to service. The transformer was finally put on load at 10:48. The urgency for this was reduced following the restoration of SGT6 as detailed below.

55 The investigations on site into the fault on SGT6 discovered a defect in the control circuitry, which had caused the smoke and resultant charred wiring. The control circuitry was rewired, checked and SGT6 was offered back for service at 10:35. This transformer was restored to service at 10:36 and provided sufficient capacity to restore the remainder of the supplies.

56 The final Aquila demand was restored at 10:52.

Investigation and Findings

Introduction

57 National Grid has well-established Transmission Procedures that deal, among other matters, with the design, procurement, commissioning and decommissioning of equipment; protection and control relay settings and the authorised skills and knowledge required by individuals for commissioning equipment. (See Appendix 2).

58 All modifications to the power system are managed through a process where a variety of specialist functions are represented. The lead responsibility for this team rests with the Network Design Manager up to the point of financial sanction, as part of the Investment Management process. This includes prioritisation of required schemes, scoping out scheme need and timing, and producing a high level design. This stage of the process is normally carried out by National Grid staff, as was the case for the Hams Hall project.

59 At the point of financial sanction, responsibility is passed to a nominated National Grid Project Manager, to manage the delivery phase of the project. This phase will include procurement, design specification, detailed design and construction, up to and including initial (stage 1) pre-energisation commissioning tests. In the case of Hams Hall, National Grid staff prepared the design specification, and engaged a contractor to undertake the subsequent detailed design and construction.

60 A representative of National Grid's Engineering Services, as usual, chaired the Commissioning Panel. This panel has responsibility for ensuring that the newly constructed works are commissioned on to the transmission system in accordance with National Grid's procedures (stage 2 commissioning). The commissioning panel meets on a regular basis and is responsible for reviewing and agreeing the method statements and schedule of commissioning tests and inspections required up to the point of commissioning on to the transmission system. A National Grid Commissioning Engineer, who is a member of the Commissioning Panel, directs the execution of all stage 2 commissioning tests.

61 The chairman of the Commissioning Panel is responsible for confirming that all the agreed test procedures relating to stage 1 pre-energisation tests are completed prior to the commencement of the stage 2 tests. On completion of each stage 2 test, a test schedule is signed to show that all entries are complete, and that the results appear correct. This is carried out by a member of the National Grid commissioning team where the tests are witnessed, or, by the Commissioning Engineer for unwitnessed tests.

62 The incident investigation has thoroughly reviewed the application of such procedures and processes to the works at Hams Hall in order to determine whether they have been rigorously applied and whether, in the light of this experience, amendments need to be made to the procedures and/or their application. The investigations have involved a thorough review of documentary evidence augmented by transcripts from control logs and interviews conducted with National Grid and contractors' staff involved in the commissioning works.

Findings

63 The investigation found that at all times the transmission system at Hams Hall was operated in a manner compliant with the Security and Quality of Supply Standards (SQSS). It also found that engineers involved in the commissioning had the appropriate training, authorisation, experience and skills to undertake the work.

64 The investigation findings are:

SGT6

65 The charred cables and localised sparking within the relay panel were caused by control circuitry that had been disconnected by a contractor during installation of a new control system.

66 At the beginning of the work to install the new substation control system for SGT6, the site wiring diagrams had been found by the contractor not to fully represent the "as installed" condition of the wiring. Specifically, wiring was found in the relay panels, which was not shown on the wiring diagram. Discussion took place between National Grid commissioning staff and the contractor's commissioning engineer to agree in principle the wiring changes needed. However, at this stage design change control procedures were not fully adhered to prior to the wiring being modified.

67 In particular, we would have expected that the omissions in the site drawings would have been referred back to the control scheme designer (in this case the contractor's design staff). The drawings should then have been amended to identify which of the additional control wiring should remain in service and which required removal, since all significant site design changes should be recorded in the design file.

68 In addition, formal processes for setting contractors to work do not appear to have been adequately followed by National Grid or its contractors. Thus, the contractor's commissioning engineer failed to identify that the control circuitry which he deemed "redundant", was connected to part of the commissioned system (specifically a current transformer). Deficiencies in the stage 1 testing performed by the contractor also failed to identify the defects.

69 The open circuited control wiring caused the overheating which was detected by National Grid site commissioning staff.

70 The decision, at 10:06 to switch out SGT6 was an appropriate action, considering the risk to construction personnel and adjacent equipment on site.

71 However, the problems encountered on SGT6 did not in themselves result in the loss of supply.

SGT8

72 SGT8 did not experience an overload condition, but was automatically switched out of service by the incorrect operation of a protection relay.

73 SGT8 is fitted with a multi-function back-up overcurrent protection relay. Only one element of this relay is used for the SGT8 application; this had been correctly set up and did not operate. However, the automatic protection operation that initiated the trip was caused by the unexpected operation of another function within the same relay that should have been disabled.

74 It was found that written instructions provided by the contractor for setting the operating parameters of the multi-function relay were ambiguous and had thus been understandably converted into an incorrect relay setting sheet, by the protection setting engineer working on National Grid's behalf. As a result, the unwanted relay functions had not been disabled prior to commissioning.

75 Normal practice, in accordance with National Grid's procedures, would be to test and commission only the active functions of the relay. The contractor correctly carried this out. However, testing of all of the functions of the relay would have identified the potential problems with those functions that should have been disabled prior to putting the equipment in service. Consequently, the presently specified off-load tests which are carried out on new relays to demonstrate that the equipment is fit for connecting to the in-service system need amending to fully reflect the increased functionality of the latest relay designs. These new tests will ensure that unwanted functionality present in the new relay designs has been effectively disabled prior to the relay being put into service.

Restoration of Demand

76 Restoration was undertaken in a controlled manner with the full co-operation of the local DNOs; good communication being maintained with all relevant parties throughout the incident.

77 Prompt restoration was helped by the presence of contractors and National Grid commissioning staff who were familiar with the site and its equipment.

78 The flexibility and skills of all staff from National Grid, contractors and the DNOs and the effective way in which they worked together on the incident greatly contributed to reducing the impact.

Actions and Recommendations

79 **All commissioning works at Hams Hall were suspended by the investigation team until assurance had been given that the cause of the incident was understood and remedial works had been completed to prevent a recurrence.**

80 **An urgent design review was instigated looking, in conjunction with the contractor, at transformer protection schemes at Hams Hall, to include all previously commissioned assets and those planned for commissioning through to completion of the works. This was completed on 11 September and necessary changes out on site were instigated.**

81 **An urgent survey was carried out of all the in-service multi-function relays of this type on the National Grid system and employed on the tripping of supergrid transformers. No similar risks of inadvertent tripping resulting from unwanted relay functionality were discovered. One other minor anomaly was detected, which has been rectified, and in any case would not have led to the circuit tripping under normal operating conditions.**

82 **The following generic recommendations apply to all relevant future commissioning works, not just the Hams Hall site:**

- **National Grid will work with the equipment manufacturer, to develop improved guidance for the use of multi-function relays;**
- **On future works, written confirmation will be required that site records align with the existing, as-installed equipment and, if not, will be amended where necessary prior to the start of new construction work;**
- **Commissioning Panels will be required to reiterate the formal control procedures for design changes at the Commissioning Panel inaugural meeting;**
- **National Grid will take steps to raise the awareness of contractors' staff of the importance of critical wiring within National Grid's relay panels;**
- **Consideration will be given to the practicalities of extending the well-established National Grid commissioning authorisation certification process to cover all contractors' staff involved in stage 1 commissioning.**

83 **The above generic recommendations will be taken forward by the general review of the management of protection systems instigated on an urgent basis by National Grid following the 28 August incident in South London.**

84 **National Grid believes that the above recommendations and their implementation will ensure, as far as reasonably practicable, that there will be no repetition of the events in this incident.**

Appendix 1: Asset Condition and Replacement Planning

85 The following section gives a summary of the main installed equipment at Hams Hall 400kV, 275kV and 132kV substations and also details of the main interconnected circuits.

Hams Hall 400kV Switchgear

86 Hams Hall 400kV substation was originally constructed in 1969 and forms part of the West Midlands 400kV network.

87 Experience has shown that a technical life of between 45 - 60 years can reasonably be expected for an outdoor substation, of design similar to Hams Hall, sited in a non-aggressive environment. Therefore replacement of the oldest parts is not expected to be required until around 2015, unless asset health monitoring indicates the need for earlier replacement.

88 The original substation included two feeder (overhead line circuit) bays, one transformer feeder bay and a bus-coupler, all fitted with air-blast circuit breakers. National Grid originally had 96 of this type of air-blast circuit breaker installed between 1966 and 1971, of which 81 remain in service. With an appropriate maintenance regime, a technical life in excess of 50 years can reasonably be expected of this type of circuit breaker.

89 The substation was extended in 1992/93 to include two Grid Supply Transformer bays (SGT6 and SGT7) feeding Hams Hall 132kV substation. The main bus-section was equipped at this time. The three circuit breakers added are SF_6 gas circuit breakers.

Substation	Circuit breaker ID	Design Type	Voltage	Description	Commissioning year
HAMH4	X105	air blast circuit breaker	400	DRAKELOW FEEDER CIRCUIT BREAKER X105	1969
HAMH4	X130	air blast circuit breaker	400	BUS COUPLER 1 CIRCUIT BREAKER X130	1969
HAMH4	X405	air blast circuit breaker	400	FECKENHAM FEEDER CIRCUIT BREAKER X405	1969
HAMH4	X510	air blast circuit breaker	400	S/GRID TRANS 5 C/BREAKER X510	1969
HAMH4	X610	SF_6 circuit breaker	400	S/GRID TRANS 6 C/BREAKER X610	1992
HAMH4	X710	SF_6 circuit breaker	400	S/GRID TRANS 7 C/BREAKER X710	1993
HAMH4	X120	SF_6 circuit breaker	400	BUS SECTION 1 C/BREAKER X120	1993
HAMH4	X230	SF_6 circuit breaker	400	BUS COUPLER 2 CIRCUIT BREAKER X230	2003
HAMH4	X810	SF_6 circuit breaker	400	S/GRID TRANS 8 C/BREAKER X810	2003
HAMH4	X910	SF_6 circuit breaker	400	S/GRID TRANS 9 C/BREAKER X910	2003

Table 1: Summary of Hams Hall 400kV circuit breakers

Hams Hall 275kV Switchgear

90 Hams Hall 275kV substation was originally constructed in 1965/66 and forms part of the West Midlands 275kV network. The substation provides supplies to Hams Hall 132kV substation via SGT1, SGT2 and SGT3.

91 The 275kV substation is fitted with the original air-blast circuit breakers. National Grid manages 132 of these circuit breakers and with a tailored maintenance regime a technical life in excess of 50 years can be expected. The 275kV substation will be replaced as part of the later stages of the West Midlands Strategy.

Substation	Circuit breaker ID	design type	Voltage	Description	Commissioning year
HAMH2	S10	air blast circuit breaker	275	BUS SECTION 1 CIRCUIT BREAKER S10	1966
HAMH2	S20	air blast circuit breaker	275	BUS SECTION 2 CIRCUIT BREAKER S20	1966
HAMH2	S30	air blast circuit breaker	275	BUS SECTION 3 CIRCUIT BREAKER S30	1965
HAMH2	S40	air blast circuit breaker	275	BUS SECTION 4 CIRCUIT BREAKER S40	1966

Table 2: Summary of circuit breakers at Hams Hall 275kV substation

Hams Hall 132kV Switchgear

92 Hams Hall 132kV Substation was originally constructed in 1956/57 to provide a 132kV feed to Midlands Electricity (now Aquila), East Midlands Electricity and the old Hams Hall A, B and C power stations. East Midlands Electricity and Aquila both have an ongoing requirement for supplies at 132kV into the foreseeable future.

93 Hams Hall 132kV substation is a double bus bar substation at which National Grid owns the busbars and 12 circuit bays comprising; five supergrid transformer switchgear bays, four bus coupler switchgear bays, two main bus section bays, one main section disconnector and five reserve section disconnectors. National Grid also owns nine spare bays. East Midlands Electricty owns two feeder bays and Aquila owns eight feeder bays.

94 The original circuit breakers are a 1940's air blast design which was installed extensively on the 132kV transmission system from the mid 1950's through to the 1960's. These circuit breakers, and the associated switchgear and bay infrastructure, are approaching the end of their technical life and are being replaced as part of the reinforcement works.

95 Of the 12 operational bays owned by National Grid, eight are fitted with the original air-blast circuit breakers. Three bays were fitted with 132kV SF_6 gas circuit breakers in 1992/93 when the 400kV SGTs were installed. A spare bay has been fitted with another type of 132kV SF_6 gas circuit breaker to facilitate the connection of SGT9 as part of the on-going reinforcement works. Both the SF_6 designs are current products available from and supported by their respective manufacturers.

Substation	Circuit breaker ID	Design type	Voltage	Description	Commissioning year
HAMH1	130	air blast circuit breaker	132	BUS COUPLER1 ACB	1956
HAMH1	220	air blast circuit breaker	132	BUS SECTION 2 ACB	1956
HAMH1	230	air blast circuit breaker	132	BUS COUPLER 2 ACB	1956
HAMH1	320	air blast circuit breaker	132	BUS SECTION 3 ACB	1958
HAMH1	110	air blast circuit breaker	132	EX - Stn Tx 1 Bay	1956
HAMH1	180	air blast circuit breaker	132	SUPERGRID T1 CIRCUIT BREAKER 180	1958
HAMH1	190	air blast circuit breaker	132	EX - Generator 1 Bay	1956
HAMH1	210	air blast circuit breaker	132	EX - Stn Tx 2 Bay	1956
HAMH1	280	air blast circuit breaker	132	SUPERGRID T2 CIRCUIT BREAKER 280	1958
HAMH1	290	air blast circuit breaker	132	EX - Generator 2 Bay	1956
HAMH1	310	air blast circuit breaker	132	Spare Bay 1	1956
HAMH1	330	air blast circuit breaker	132	BUS COUPLER 3 ACB	1957
HAMH1	390	air blast circuit breaker	132	EX – Generator 3 Bay	1956
HAMH1	410	air blast circuit breaker	132	Spare Bay 6	1956
HAMH1	430	air blast circuit breaker	132	BUS COUPLER 4 ACB	1957
HAMH1	490	air blast circuit breaker	132	EX – Generator 4 Bay	1956
HAMH1	590	air blast circuit breaker	132	EX – Generator 5 Bay	1956
HAMH1	980	SF_6 circuit breaker	132	SUPERGRID T9 CIRCUIT BREAKER 980	2003
HAMH1	380	SF_6 circuit breaker	132	SUPERGRID T3 CIRCUIT BREAKER 380	1993
HAMH1	880	SF_6 circuit breaker	132	SUPERGRID T8 CIRCUIT BREAKER 880	1992
HAMH1	680	SF_6 circuit breaker	132	SUPERGRID T6 CIRCUIT BREAKER 680	1993

Table 3: National Grid owned circuit breakers at Hams Hall 132kV substation

Transformers

96 Prior to the current reinforcement works Hams Hall 132kV substation was supplied by 3 x 275/132kV 120MVA supergrid transformers (SGT1, 2 and 3) and 2 x 400/132kV 240MVA transformers (SGT6 and SGT7), thereby sharing the load between the 275kV and 400kV substations. The current works include the addition of two further 400/132kV SGTs which will allow the entire 132kV load to be supplied from the 400kV substation and remove reliance on the 275kV substation. This is in line with the reinforcement strategy to uprate the 275kV network in this area to 400kV. On completion of this work the existing 275/132kV transformers will become redundant.

97 In addition to the grid supply transformers listed above there is a 400/275kV interconnection transformer, SGT5, which provides a 275kV feed to Nechells 275kV substation from Hams Hall 400kV substation.

98 National Grid has conducted considerable research into the deterioration modes and life-limiting processes associated with transformers. As a result of this improved understanding, transformers are generally expected to have an asset life in excess of the associated substation assets, unless they belong to a design group with a known defect. It is expected that 50% of National Grid transformers will have a reliable service life in excess of 55 years.

99 SGT1 and SGT2 are 275/132kV transformers which belong to a design group of 12 (two at Hams Hall) owned and operated by National Grid. This family has a known design problem which results in the winding clamping arrangement becoming loose with age and resulting in internal arcing and sparking (detected and monitored via oil analysis). SGT2 has undergone internal remedial works, but this is known to be a temporary solution. These transformers are considered to be approaching the end of their reliable life and will be decommissioned as part of the Hams Hall scheme.

100 SGT3 is a 275/132kV transformer belonging to a design group with a known weakness that results in overheating of the winding. However, routine monitoring of dissolved gases in the transformer oil shows no indication of the design fault developing in this particular unit. Therefore there is no cause for concern over the condition of this transformer, however, it is also being decommissioned as part of the Hams Hall scheme.

101 The original SGT5 was installed in 1969 during the construction of the 400kV substation. This transformer failed in 1998 and was replaced with a national spare, the present SGT5.

102 SGT6 and SGT7 have seen only 10 years of service and are relatively modern transformers. There is no design weakness associated with this family of transformers and routine monitoring gives no cause for concern.

103 SGT8 and SGT9 are replacements for the original 120 MVA units (SGT1, SGT2 and SGT3) discussed above, and will be commissioned during 2003.

Protection Systems

104 The majority of the transformer protection systems at Hams Hall are modern electronic relays that have replaced older electro-mechanical devices.

Transformer	Overall protection	HV backup protection	LV backup protection	Installation date
SGT1	B3 (Main 1) CAG34 (Main 2)	TJX (OC) CAG37 (HSOC)	MCGG22 (EF)	1975
SGT2	B3 (Main 1) CAG34 (Main 2)	TJX (OC) CAG37 (HSOC)	MCGG22 (EF)	1975
SGT3	3B3 (Main 1) CAG34 (Main 2)	TJV (OC) CAG37 (HSOC)	MCGG22 (EF)	1969
SGT5	3B3 (Main 1) CAG34 (Main 2)	TJV (OC) CAG39 (HSOC)	MCGG22 (EF)	1970
SGT6	B3 (Main 1) B3 (Main 2)	MSGG62 (OC) MCAG39 (HSOC)	MCGG52 (EF) MCGG52 (OC)	1992
SGT7	B3 (Main 1) B3 (Main 2)	MSGG62 (OC) MCAG39 (HSOC)	MCGG52 (EF) MCGG52 (OC)	1992
SGT8	MFAC34 (Main 1) MFAC34 (Main 2)	MCGG62 (OC) MCAG39 (HSOC)	MCGG22 (EF) KCGG142 (IOC)	2003
SGT9	MFAC34 (Main 1) MFAC34 (Main 2)	MCGG62 (OC) MCAG39 (HSOC)	MCGG22 (EF) KCGG142 (IOC)	2003

OC = overcurrent protection HSOC = High speed overcurrent protection
IOC = interlocked overcurrent protection EF = earth fault protection

Table 4: Summary of Feeder Protections

Control Systems

105 The Substation Control Systems (SCS) facilitate remote operation of substation equipment from both National Control and the local substation. The SCS also provides remote monitoring, operational metering, event logging and alarm handling facilities. Substation automation functions (e.g. auto-reclose, automatic voltage control or synchronisation) may be embedded in the SCS or facilitated by stand-alone units linked to the SCS.

Substation	**Control System**	**Year Commissioned**
Hams Hall 400kV	METRO	Replacement in progress 2003/04
Hams Hall 275kV	METRO	Replacement in progress 2003/04

Table 5: Substation control systems

Appendix 2: Details of National Grid's Key Policies and Procedures Relevant to the Incident

Transmission Procedures

106 National Grid has well-established and rigorously applied Transmission Procedures that deal, among other matters, with the design, procurement, commissioning and decommissioning of equipment; protection and control relay settings; and the authorised skills and knowledge required by individuals for commissioning equipment.

Design Management

107 The design work on the Hams Hall substations was carried out under transmission management procedures. In addition to procedural requirements, the detailed arrangements focused on individual responsibilities, reporting on the status of the design, the chronology of a programme, resource estimates and monitoring data, design reviews and documentation control.

108 Responsibility for ensuring that designs were compliant and accordance with National Grid engineering policy lay with the design manager. The project development engineer was charged with securing outline design solutions from a design engineer, in order to enable scheme costing, and to assemble a team to develop the scoping report and agree a development progress plan.

109 As leader of the delivery stage, the project manager was responsible for interfacing with the design engineer to ensure that design requirements were integrated with the total project and that the design was monitored and progressed to meet the project requirements.

110 During company restructuring these procedures have been updated for application to new projects and describes the current design management process for construction projects teams. The scope of the documents covers the design of the power system, site infrastructure and the external environment. The procedures detail the design management process, specifically defining tasks required to ensure design control is maintained through the delivery stage of the project.

Procurement

111 National Grid operates a two-stage supplier qualification process. The first stage is an independent assessment and is consistent with that used by many other Utilities. The second stage embraces detailed in house requirements covering all aspects of the suppliers' capability, and is applicable to all suppliers who provide products for, or who work on, our electricity system. In addition to these requirements, the capability and performance of our key suppliers is continually assessed and recorded on a regular basis. Suppliers failing to meet the required standards are tracked through an improvement plan, until service levels reach required standards. If service levels continue to deteriorate, suppliers will ultimately be removed from the approved vendor list.

Commissioning and Decommissioning

112 The equipment commissioning and decommissioning procedure defines National Grid requirements for equipment covered by the Transmission Licence. The procedure lays down a framework of requirements that apply to its major construction projects.

113 The four main commissioning objectives are to fulfil statutory requirements (principally health and safety and environmental); to maintain system security; to test equipment performance and manage data; and to meet contractual conditions.

114 Complex projects involving related and staged activities at more than one site require the preparation of a Project Co-ordination Programme. This programme details staging, commissioning and maintenance requirements and who is responsible for what. The programme team should have representatives from National Grid's commissioning panels for construction, engineering services and operations and trading. It should be chaired by a representative from engineering services.

115 The Commissioning Programme consists of a timed and staged plan for a series of inspections, tests and switching operations which verify that the equipment is suitable for operational service. The first stage of the programme consists of a Pre-commissioning Inspection Schedule, Off-load Commissioning Test Programme and Pre-energisation Inspection Schedule (stage 1 commissioning). The second stage comprises a Commissioning Method Statement and Commissioning Switching Programme (stage 2 commissioning), both of which must be rigorously adhered to and can only be deviated from by joint agreement of the contractor and commissioning engineer, and a Post-commissioning Inspection Schedule.

Protection and Control Relay Settings

116 Protection equipment receives electrical or mechanical inputs and, when it detects an abnormal condition, initiates signals to cause automatic disconnection from the system. Control equipment signals other equipment to reinstate a circuit following a fault, reconfigure a circuit in a predetermined way or change system conditions.

117 The definition of a relay in this procedure, is all protection and control equipment which requires a setting. With traditional relays only one setting could be held. Modern numerical relays can hold multiple setting groups.

118 A substation control system (SCS) controls and/or collects data and provides an operational interface with a remote control point. National Grid's database for recording relay settings is known as Multi Access Relay Settings, or MARS.

119 The procedure for defining the management process for the production, application, dissemination and recording of protection and control relay settings applies to all such equipment owned by National Grid or for which the company has arranged to carry out the settings. The process can also be carried out by nominated outside engineers, for example by a supplier or as part of ongoing support.

120 The overall accountability for carrying out the relay setting process is held by a manager nominated by National Grid's Construction Manager. The Construction Manager or the supplier nominates a Settings Engineer, who carries out the calculations and setting processes defined in the procedure.

121 A National Grid Initiating Engineer is accountable for settings provided by a supplier and uses professional judgement to decide whether a full or more rudimentary check is required.

122 The Settings Engineer is required to carry out protection and control setting calculations in accordance with the defined relay setting policies and system data, and to record the details including all calculations. The setting must then be recorded in the MARS database.

123 Procedures for emergencies apply when the timescale for preparation is urgent. In such circumstances when the Settings Engineer needs to convey relay settings orally, the recipient must produce a legible manuscript copy and repeat the copy to the sender. When the settings are conveyed electronically, the contents must still be verified orally.

124 When settings need renewing or revising due to equipment failure, a Commissioning Panel agrees the timescale for the work with the Settings Management Co-ordination Engineer. Settings changes to in-service equipment are routed through Operations & Trading – Policy and Compliance.

125 Documentation requirements include completion of a Relay Settings Data Sheet, a Protection Settings Sheet specifying the settings to be applied, a software configuration file for non-integrated numerical relays and identification of all circuits at each substation in an index in construction files and engineering services site files. The index is to be prepared by a MARS administrator and forwarded to engineering services when updates occur.

Commissioning Authorisation

126 A structured programme of training and assessment of all engineers with formal commissioning responsibilities has been in place since 1997. The training and assessment leads to a certificate of authorisation. National Grid's Commissioning Authorisation procedure lays down training assessment and documentation requirements.

127 Line managers are responsible for providing local training and assessment, and confirmation of authorisation which should be assessed annually at the time of the individual's Performance and Development Review. Engineers are responsible for maintaining their authorisation documentation and for reviewing with their line manager whether their training and experience is sufficient for them to retain their authorisation.

128 Training and assessment is modular and ranges from basic technical principles, practical commissioning exercises and switching programme tutorials through to advanced technical and management modules.

Appendix 3: How National Grid plans and operates the transmission system and secures demand

Introduction

129 National Grid plans and operates the transmission system in accordance with the Security and Quality of Supply Standard (SQSS), which is a requirement of the Transmission Licence.

130 National Grid's system performance against the SQSS is reported annually to Ofgem in accordance with the Transmission Licence and is publicly available. Overall, an improved level of system performance has been achieved since privatisation. Performance is reported in terms of availability, system security and quality of service. Average annual system availability and winter peak availability rose significantly until 1999 and have remained at a high level. The annualised number of losses of supply and unsupplied energy varies on a year by year basis with no performance degradation. Quality of supply is reported to Ofgem each year in terms of compliance with statutory limits and shows only five voltage and eleven frequency excursions since 1990, with no frequency excursions for the last seven years.

Main Interconnected Transmission System

131 In essence, the standard determines the degree of additional resilience that must be built in to the main interconnected transmission system so that the system is robust against credible equipment failures and the need to maintain the assets. Typically, the main system must be able to withstand the unplanned loss of a double circuit (two overhead lines hanging on the same transmission towers), although smaller demand groups are permitted to be dependent on a single circuit when circuit outages are required.

132 This is illustrated in figure 11. When the double circuit is lost, the flow of electricity on the remaining circuits will increase to compensate for the loss. The transmission system is designed and operated so as to be able to accommodate these additional flows.

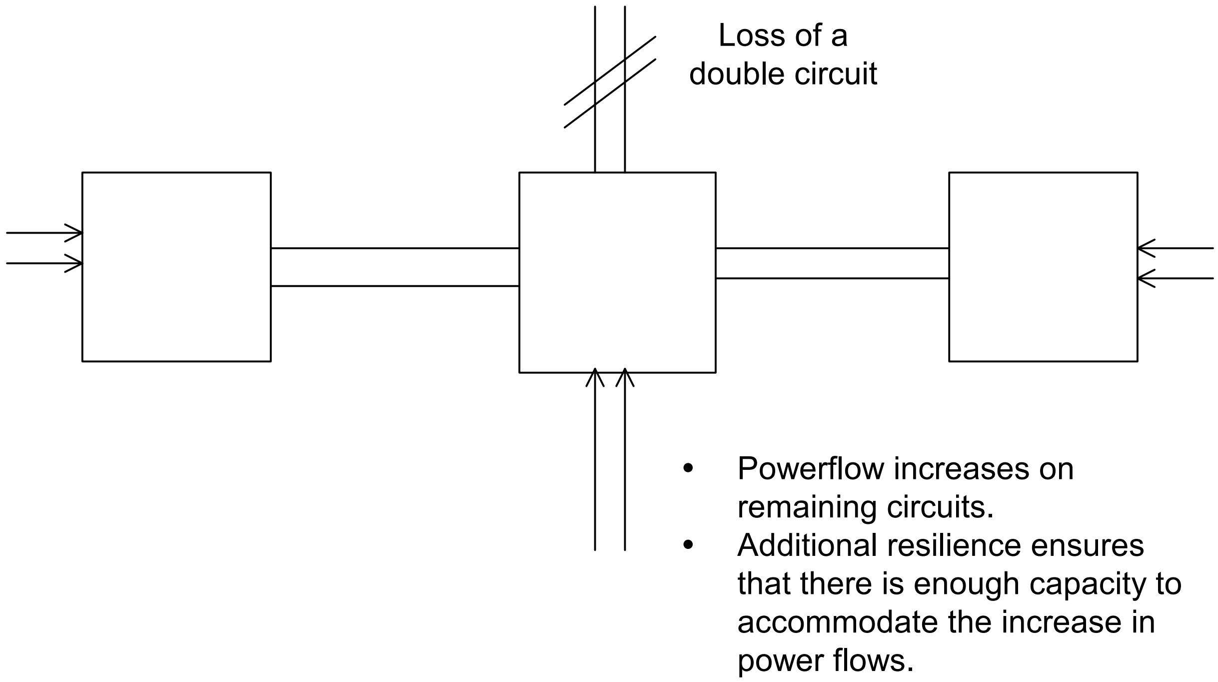


Figure 11 : Loss of double circuit on main interconnected system

133 The design and operation of a transmission system must ensure that prior to any unplanned circuit outage, the voltage will be within the pre-fault planning/operational voltage levels. Following the unplanned outage, the voltage should not exceed the voltage step change limits or deviate outside the steady state voltage limits outlined in the SQSS.

Demand Connection Criteria

134 In essence, the standards determine the degree of additional resilience that must be provided to meet the demand that is supplied from the main interconnected transmission systems. The degree of resilience is based on the forecast maximum demand for that group provided by the distribution network operator.

135 This is illustrated in figure 12. When a supergrid transformer is lost, during a planned maintenance of another supergrid transformer, the flow in the remaining supergrid transformer will increase to compensate for the loss. There should be sufficient supergrid transformer capacity to be able to accommodate these additional flows.

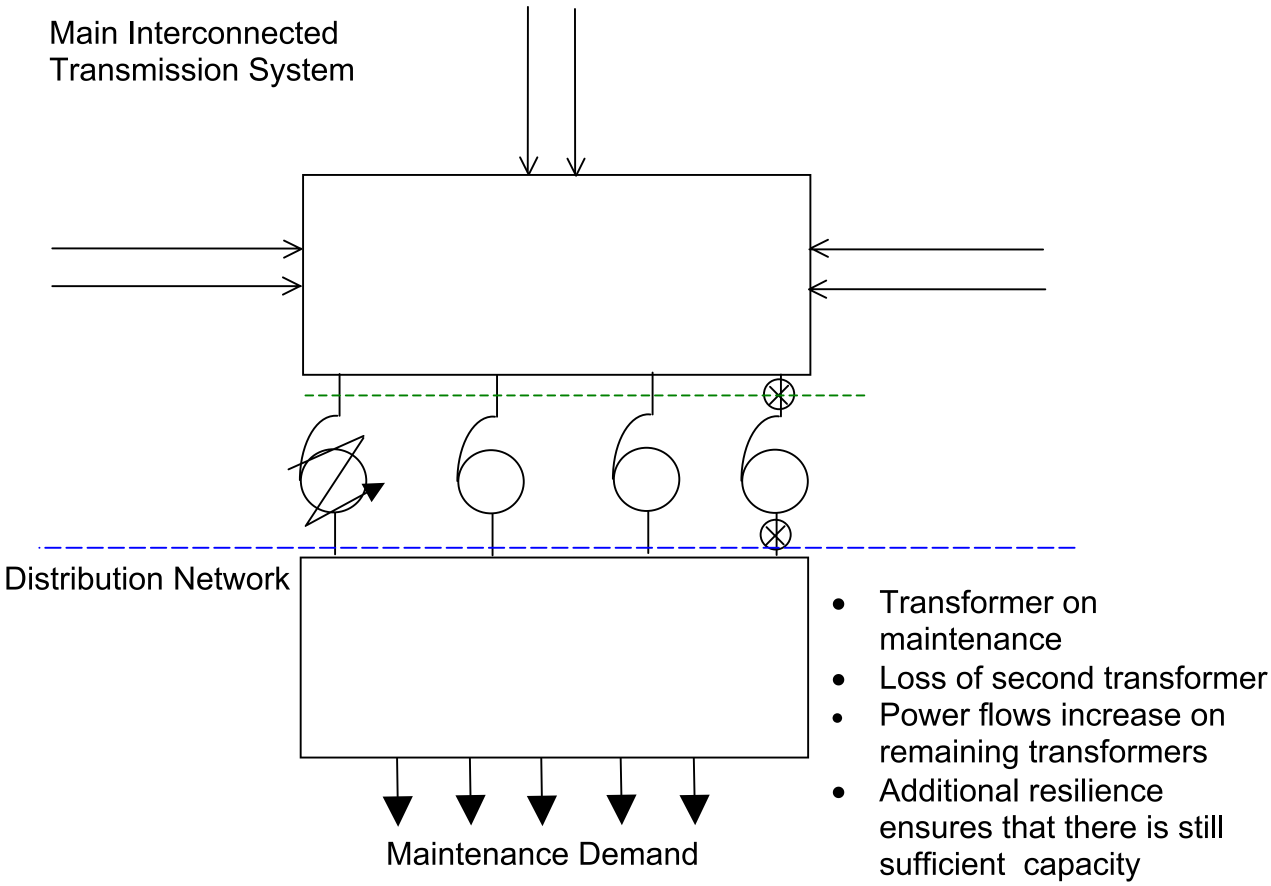


Figure 12 : Generic diagram showing capacity requirements for demand connections

Conclusion

136 The SQSS was subject to a review in the mid 1990's, and following extensive consultation with the industry and customers, a revised standard was approved by Ofgem. The provisions of the SQSS bear comparison with standards applied elsewhere in the world and are equivalent to those that existed before privatisation of the industry.

137 The level of additional resilience built in to the transmission system is a balance of risk between cost and security. The SQSS has delivered an extremely high level of security and reliability by international standards. It would require a very high level of additional cost and investment to increase the current level of security across the entire system even marginally.

138 Application of the security standard, supported by a sustained high level of investment, has delivered an extremely low level of customer demand lost, as a result of events on the transmission system. The average level of unsupplied energy over the past five years has been 0.0001% of the total supplied. For comparison this is 27 times lower than the average reported through an international benchmarking exercise involving 16 major transmission system operators in 1999/2000 and 2000/2001.

139 During winter months the system is usually operated with all circuits in service. Where this is not possible, for example due to extensive construction works or equipment failure, there is sufficient flexibility to ensure the security standard is met. During the summer months, when demand for electricity is lower, circuits are taken out of service for maintenance and construction works. These circuit outages are carefully co-ordinated with each other, with distribution network operator outages, generation outages and demand profiles, in order to ensure that the system remains compliant with the security standards.

Appendix 4: Switching Operations During the Incident

	TIME	SITE	EQUIPMENT	
SGT6 off load	05/09/03 10:09:42	HAMS HALL 132	680 BREAKER	OPEN
SGT8 & SGT3 trip	05/09/03 10:10:08	HAMS HALL 132	880 BREAKER	OPEN
	05/09/03 10:10:17	HAMS HALL 132	380 BREAKER	OPEN
	05/09/03 10:10:17	HAMS HALL 132	SGT8 PROTECTION	OPERATED
	05/09/03 10:10:17	HAMS HALL 132	SGT8 PROTECTION	RESET
	05/09/03 10:10:35	HAMS HALL 132	SGT3 PROTECTION	OPERATED
	05/09/03 10:10:43	HAMS HALL 132	SGT3 PROTECTION	RESET
Commence restoration of SGT2	05/09/03 10:18:39	HAMS HALL 275	S24 ISOLATOR	CLOSE
SGT3 on load	05/09/03 10:21:35	HAMS HALL 132	380 BREAKER	CLOSE
Restoration of SGT2	05/09/03 10:31:45	HAMS HALL 275	H23 ISOLATOR	CLOSE
	05/09/03 10:32:18	HAMS HALL 275	S36 ISOLATOR	CLOSE
SGT6 on load	05/09/03 10:36:38	HAMS HALL 132	680 BREAKER	CLOSE
Restoration of SGT2	05/09/03 10:39:43	HAMS HALL 275	S20 BREAKER	CLOSE
Hot standby of SGT1	05/09/03 10:47:07	HAMS HALL 275	H13 ISOLATOR	CLOSE
SGT2 on load	05/09/03 10:48:54	HAMS HALL 132	280 BREAKER	CLOSE
Hot standby of SGT1	05/09/03 10:51:27	HAMS HALL 275	S30 BREAKER	CLOSE
	05/09/03 10:52:52	HAMS HALL 275	S46 ISOLATOR	CLOSE

Appendix 5: Purpose of Automatic Protection Equipment and the use of Multifunction Protection Relays

140 During normal operation the power system supplies load current. At times of peak demand a 400kV circuit may be subject to load current which is as high as 5,200 amperes. However, when the 400kV power system is subject to a fault (short circuit) the current increases significantly, and could rise as high as 63,000 amperes. These very high fault currents are disruptive and potentially damaging to the power system and must be quickly removed.

141 The purpose of 'protection' is to detect a fault on the power system and then instruct the appropriate circuit breakers to automatically disconnect the faulty item of equipment from the power system. This process needs to be accomplished as fast as possible to prevent:

(a) unnecessary damage to faulty equipment
(b) potential damage to healthy equipment – that is required to carry the high fault current until the fault is removed
(c) unstable operation of generating equipment – leading to loss of generation
(d) loss of supply to customers

142 Two types of protection are applied to the transmission system: main protection which protects a specified item of equipment, e.g. a transformer, an overhead line circuit, or a cable circuit; and backup protection which provides backup if the main protection fails.

143 Main protection will not operate for either load current or fault current (other than a fault on the equipment it is protecting). The same is not true for backup protection. It will operate for any current, either load or fault current, that is above its setting.

144 A multifunction relay is a Programmable Logic Controller comprising opto-isolated inputs, (for electrical segregation) and a number of output relays which can be selected against a library of protection functionality held within the logic controller. The functionality logic available is not 'user definable'. It is essentially a sequence of selectable logic building blocks, which are employed to meet the application requirements set by the customer.

145 This type of relay has a flexible configuration base and therefore have the ability to be applied to numerous protection applications (e.g. overcurrent, earthfault). The relay settings applied consist of both configuration and power system dependant variables. The configuration settings are applied by setting function links and masking inputs/outputs available from a matrix of options. The power system dependant settings are then applied to the selected functions and the external scheme wiring applied to the correct relay input/outputs.

146 This series of relays also has a communication capability and can all be connected to a common 'bus' thereby providing other functions such as remote interrogation, remote setting changes and analogue measurements. In the National Grid applications the remote functionality has not been activated.

147 There is a varied use of multifunction relays on the National Grid system. They fall into two basic categories. The first category is general protection functions such as back-up overcurrent and earth fault, interlocked overcurrent, directional overcurrent, and standby earth fault. Relays in this category provide tripping functions. The second category comprises relays undertaking control orientated functions, which include delayed auto reclose, synchronising, auto close, auto isolation etc.

148 The number of multifunction relays in use on the National Grid system from the same manufacturer as those installed at Hams Hall is 188, with 121 of them having direct trip capability.

149 The cause of the incident at Hams Hall on SGT8 related to an over-current element within the relay (**I**>), which was not designed to be part of the protection scheme. The said element was left ‘assigned’ to an output relay which was wired and used as part of the design. This is the default position on leaving the factory, requiring deselection by reference to the setting sheet to disable the output.

150 The current setting of over-current element (**I**>) was left set to a nominal 1000A (**I**s = 1 on a 1000/1 CT ratio). The associated time for this element was left set to an instantaneous trip (DT characteristic with 0 sec set). When the load on SGT8 exceeded 1000A at 132kV the over-current element operated to trip the circuit.

Appendix 6: References

Transmission Security and Quality of Supply Standard:
http://www.nationalgrid.com/uk/library/documents/mn_license_standard.html

Grid Code
http://www.nationalgrid.com/uk/indinfo/grid_code/index.html

System Performance Report 2002/03
http://www.nationalgrid.com/uk/library/documents/pdfs/System_performance_Report_2002_03.pdf

Transmission Licence
http://www.nationalgrid.com/uk/library/documents/mn_transmission_licence.html