Report

A LOAD FLOW MODELLING SERVICE

Prepared for:
ELEXON

Prepared by:

Power Technologies International (PTI)
Cranford Court
King Street
Knutsford
Cheshire
WA16 8BW
United Kingdom

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CONTENT

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2 PROJECT OBJECTIVES AND INTRODUCTION

Power Technologies International (PTI) has been commissioned to assist ELEXON and TLFMG (Transmission Loss Factor Modification Group) in the assessment procedure of the BSC (Balancing and Settlement Code) Modification Proposals P75 ('Introduction of Zonal Transmission Losses') and P82 ('Introduction of Zonal Transmission Losses on an Average Basis'). A summary of the key features of each proposal is summarised in Table 1.

Table 1: Summary of the key features of the Modification proposals P75 and P82

Feature	Modification Proposal P75	Modification Proposal P82
Transmission Loss Factor Methodology (TLFM)	'Marginal'	'Scaled Marginal' (i.e. scaling factor of approximately 0.5)
Transmission Loss Factor (TLF) Calculation	Half hourly ex-post	Annual ex-ante
Validity of TLFs	One Settlement Period	One Year (April to March)
Zonal Groupings	Generation –TNUoS zones Demand – GSP Groups	Generation – GSP Groups Demand – GSP Groups
Network Configuration Data	Historic or 'real time'	Historic
'Averaging' Process for Converting Nodal TLFs into Zonal TLFs	'Demand-weighted' averaging	'Demand-weighted' averaging
'Averaging' Process for Converting Half-hourly TLFs into Annual TLFs	Not applicable	Time-weighted averaging

Specifically, PTI has been tasked to:

- perform calculations of TLFs & TLMs for a specified number of Settlement Periods (SPs) for Modification P75 and P82;
- present the results in a form suitable for the assessment procedure; and
- draw attention to potential issues with the fundamentals of the two marginal approaches proposed (P75 and P82) arising from the exercise.

A large number of load flow calculations, marginal TLF calculations and post processing calculations were performed. All results from these calculations as well as the input data received from ELEXON were delivered to ELEXON in electronic format on a CD. The results were presented to TLFMG and discussed on several occasions. The results were also presented to a broader audience during the seminar organised by ELEXON on 24 September 2002.

This report presents a suitable selection of the project results. Section 2 presents input data received from ELEXON for the modelling exercise in this project. Section 3 presents the assumptions made and section 4 raises some methodological issues with the proposed approaches (P75 and P82) noted in the modelling exercise in this project. Section 5 presents the results separately for Modification Proposals P75 and P82. The report does not have conclusions as they will arise from the TLFMG's assessment procedure.

3 INPUT DATA FOR THE MODELLING EXERCISE

3.1 Settlement Period data

Table 2: List of Settlement Periods for which delivery and offtake metered volumes data were provided by ELEXON

Demand and Generation Data – Settlement Periods		
Day	**Settlement Period**	**Comment**
01 August 2001 (Wednesday)	8 (03:30 – 04:00)	Summer weekday trough (night)
01 August 2001 (Wednesday)	36 (17:30 – 18:00)	Summer weekday trough (day) **
10 October 2001 (Wednesday)	1 – 48	Autumn whole day (weekday)
10 October 2001 (Wednesday)	25 (12:00 – 12:30)	Weekday daytime *
11 October 2001 (Thursday)	11 (05:00 – 05:30)	Weekday night
13 October 2001 (Saturday)	25 (12:00 – 12:30)	Weekend daytime
14 October 2001 (Sunday)	11 (05:00 – 05:30)	Weekend night
31 October 2001 (Wednesday)	30 (14:30 – 15:00)	Import over French connector
07 November 2001 (Wednesday)	30 (14:30 – 15:00)	Export over French connector
02 January 2002 (Wednesday)	36 (17:30 – 18:00)	Winter peak (daytime)
02 January 2002 (Wednesday)	8 (03:30 – 04:00)	Winter peak (night) **

* - Also used in the set of baseline cases
** - Used in calculation of annual average TLFs only

Delivery and offtake metered volumes data for a number of Settlement Periods from the recent past were provided by ELEXON for the calculation of TLFs and TLMs for a number of specified scenarios (**Table 2**).

These scenarios, specified by the Terms of Reference, were designed with the aim to demonstrate the key representative features of Modification Proposals P75 and P82, required by the TLFMG for the assessment procedure. For this purpose each of the scenarios combine selected Settlement Period data with particular network data. Which Settlement Periods are used in particular task (calculation exercise) is indicated appropriately in this report where the results are presented.

Some inconsistencies in metered volumes data were resolved in manner described in the section 3 (Modelling Assumptions)

Past delivery and offtake metered volumes data for the representative SPs were used in calculating characteristic TLFs & TLMs.

3.2 Network data

In order to enable load flow calculations and calculations of marginal TLFs, the delivery and offtake metered volumes data for specific Settlement Periods (**Table 2**) were accompanied with appropriate detailed network data. The list if "indicative" networks for which data were provided is given in **Table 3**.

Network data provided and indicated in **Table 3** were considered to be "indicative", i.e. as they actually happened to be on the day considered. The data contained lists of network elements in operation and their electric parameters required for the calculations. The network on 02 January 2002 was also regarded as "intact", as it was considered to be most complete (i.e. to have the largest and most complete set of network elements in operation). A "representative" network also featured in the calculations performed. It was made up from the intact network by taking into account overall network availability indices form the NGC's SYS (electric parameters of the network branches were proportionally increased).

Table 3: List of network data provided by ELEXON

Network Data	
Network	**Comment (relation to SPs in Table 2)**
01 August 2001 – Weekday, summer trough	Summer weekday trough (Wednesday)
10 October 2001 – Weekday	Whole weekday (Wednesday) *
11 October 2001 Weekday	Weekend night (Thursday)
13 October 2001 – Weekend	Weekend daytime (Saturday)
14 October 2001 – Weekend	Weekend night (Sunday)
02 January 2002 – Winter peak	Winter peak (Wednesday)

* - Also used in calculations concerned with flows on the French inter-connector

Actual network data from the past were used to match the considered Settlement Periods' metered volumes.

4 MODELLING ASSUMPTIONS

A number of assumptions had to be made for the process of calculating TLFs and TLMs. However, it is important to recognise that some of these assumptions are inherent to the calculation methodology applied (and required by the P75 and P82) and some were made due to inconsistencies in the input data received for the modelling exercise. The latter assumptions are not expected to feature once a chosen modification is implemented. The list of key assumptions is as follows:

a) MW injections were calculated from the metered volumes assuming they are constant (average).

b) Typical demand power factors published in NGC's SYS were used to calculate reactive power injections.

c) It was assumed that "offtake" metered volumes/injections were accurate and then the "delivery" volumes/injections were calculated to balance "offtake" metered volumes/injections and the calculated variable active power system losses, while maintaining relative "deliveries" among the generators (this assumption was necessary due to inconsistencies in the input data provided).

d) Load flow assumptions:

- Generation P is calculated as described above
- Generation Q is calculated automatically by setting voltage target to 1.03 p.u.
- Load P is calculated from the metered volumes
- Load Q is calculated from typical demand power factors given in the NGC's SYS
- Transformer tap changers are set according to information in the NGC's SYS for each voltage level
- Transformer target voltage is set to produce reasonable voltage profile (between 0.97 and 1.03 p.u.)
- SVC's target voltage is set to values recommended in the NGC's SYS

e) AC load flow calculations were using the standard NGC's slack at Cowley.

f) PTI's commercial software product PSS/E and its OPF module were used for load flow calculations and calculation of marginal TLFs respectively.

g) Out of obtained TLFs for active power injections (TLF_{Pij}) and TLFs for reactive power injections (TLF_{Qij}), unique TLFs were calculated that relate only to active power injections, while providing for the total losses incurred from a node. These unique TLFs were calculated as $TLF_{ij} = (TLF_{Pij} \times P_{ij} + TLF_{Qij} \times Q_{ij}) / P_{ij}$.

h) On the basis of information in the NGC's SYS, the fixed losses were assumed to be 200MW (peak day), 180MW (trough day) and 190MW (other periods – autumn days in this exercise). In a "go live" implementation more accurate figures could be calculated and used.

i) For the purpose of calculating TLMs, these fixed losses were smeared across generators, proportionally to their power output.

Intention was to minimise number of assumptions while aiming at high accuracy and representation of physical phenomena

5 SOME ISSUES WITH THE PROPOSED APPROACHES (P75 AND P82) TO ALLOCATION OF LOSSES BASED ON MARGINAL TLFS

5.1 Choice of the slack node

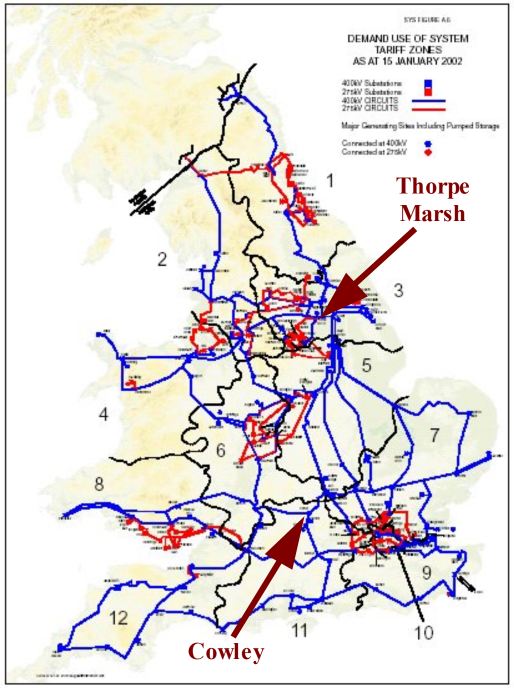

Figure 1: Location of the two considered alternative slack nodes (Cowley and Thorpe Marsh)

During the calculation exercise it was noted that the choice of slack node potentially matters more than initially expected.

In order to get an indication about sensitivity of TLMs on the choice of slack node a simple exercise was performed. Calculations of TLMs were performed using network data and metered volumes for 02 January 2002, Settlement Period 36, while switching the slack node between Cowley (the standard NGC's slack node) and Thorpe Marsh (**Figure 1**). The overall results are presented in **Table 4**.

Table 4: Differences in TLMs due to switching the slack node between Cowley and Thorpe Marsh

	Generation TLMs		Demand TLMs	
	Diff/(TLM-1)	Diff/TLM	Diff/(TLM-1)	Diff/TLM
Average	9.23%	0.30%	9,96%	0.28%
SD	14.26%	0.17%	19.05%	0.16%

Illustrative explanation: Assume a generation (delivery) metered volume of 1000MWh and a TLM for this generation of 0.94. Such a TLM would attribute 60MWh of losses to this generation. Due to the indicated change in slack node (between Cowley and Thorpe Marsh) this 60MWh of attributed losses would change for 9.23%, on average.

The choice of slack node potentially matters more than initially expected.

5.2 Power factor

The flow of reactive powers causes active power losses.

In order to illustrate indicative sensitivity of nodal TLFs and TLMs to introduction/variation of power factors for demand metered volumes a simple exercise was performed. Calculations of TLFs/TLMs were performed using network data and metered volumes for 02 January 2002, Settlement Period 36 with:

- power factors equal to 1 for all demand ("offtake") metered volumes; and
- typical power factors equal to values indicated for demand in NGC's SYS (Seven Years Statement).

The comparison of the results is presented in **Table 5**. The effect of power factors as they are indicated in NGC's SYS was much more tangible at the level of TLFs than at the level of TLMs. This indicates:

a) that reactive powers should not be ignored; and

b) a possible need for further consideration

Table 5: Comparison of nodal TLMs and TLFs calculated when power factors are 1 for all demand metered volumes and when they are typical, as indicated in NGC's SYS

	Nodal TLMs		Nodal TLFs *
	Generation	Demand	
	Diff/TLM	Diff/TLM	Diff/TLF
Average	0.22%	0.23%	14.22%
Minimum	0.00%	0.00%	0.08%
Maximum	1.57%	1.32%	371.51% *
SD	0.24%	0.18%	31.07%

* - Nodal TLFs are the same for both generation and demand

** - Such large figures are associated with nodes that originally had very small TLFs

TLFMG recognised that there are some issues arising from the modelling that may need further investigation. Nevertheless, TLFMG expressed that they did not expect these issues to have a significant impact on modelling results.

PROJECT RESULTS FOR

MODIFICATION PROPOSAL P75
('INTRODUCTION OF ZONAL TRANSMISSION LOSSES')

6 PROJECT RESULTS

6.1 Modification Proposal P75 ('Introduction of Zonal Transmission Losses')

Modification Proposal P75 proposes calculation of zonal TLMs based on marginal non-scaled ½ h TLFs. The proposed zones are GSPG zones for demand and TNUoS (gen) zones for generation (**Figure 2** and **Figure 3** respectively). An additional demand zone, GSPG zone 0, is set specifically for the Scottish inter-connectors (as required by the Terms of Reference). Zonal TLFs for demand and generation (required in calculation of zonal TLMs) were calculated as average of nodal TLFs weighted by demand and generation respectively. This approach preserves amount of losses originally attributed to each zone when using nodal TLFs.

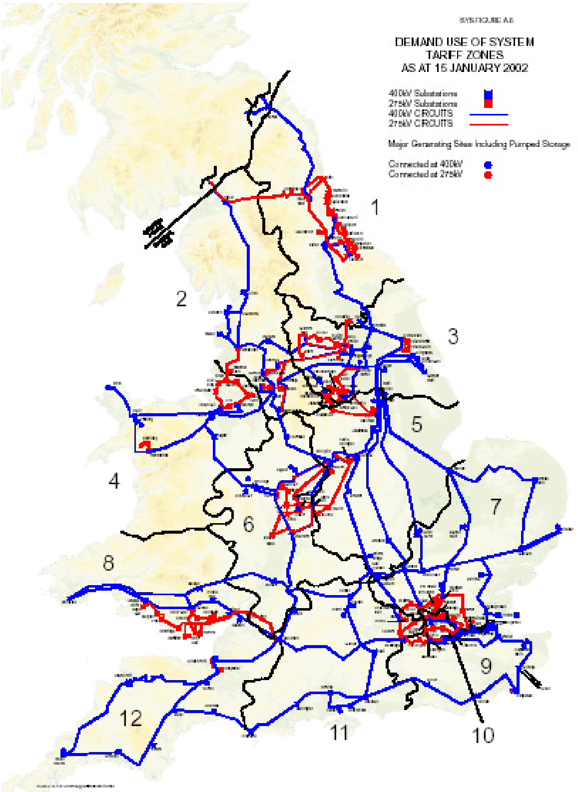

Figure 2: Geographical presentation of GSPG zones for demand

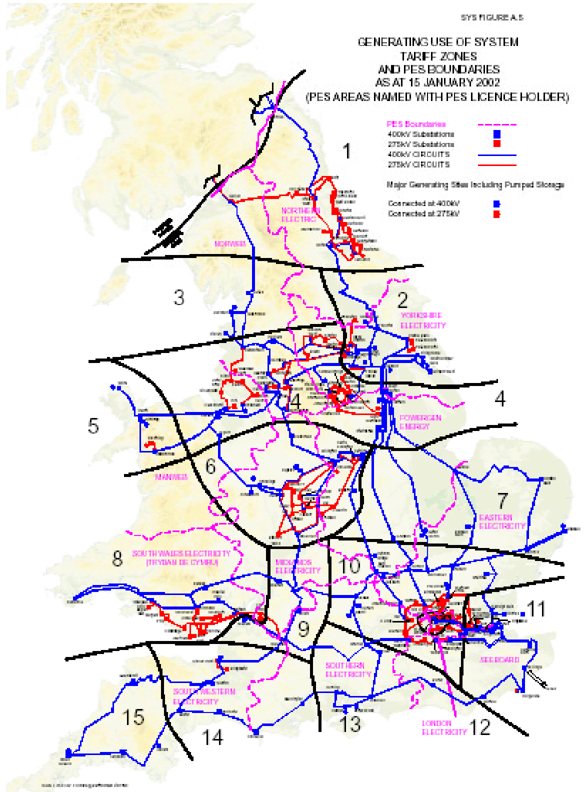

Figure 3: Geographical presentation of TNUoS (gen) zones for generation

6.1.1 Task 1: Baseline TLFs and TLMs

Currently BSC calculates TLMs with TLFs set to zero. Data for 02 January 2002, Settlement Period 36 (winter peak) were used to illustrate the change use of P75's TLFs would introduce in calculated zonal TLMs. **Figure 4** presents GSPG zonal TLMs for demand as calculated at present and as they would be calculated by P75. GSPG zone 0 is set specifically for the Scottish inter-connectors. Zonal TLM for GSPG 0 is circled in **Figure 4** as it is distorted by the way TLMs are calculated. However, this distortion does not appear and does not have any effect when there is no demand on the Scottish inter-connectors (a usual condition). This comment applies through all presentations of GSPG zone 0 TLMs, related to P75 in this Report. **Figure 5** presents TNUoS (gen) zonal TLMs for generation as calculated at present and as they would be calculated by P75.

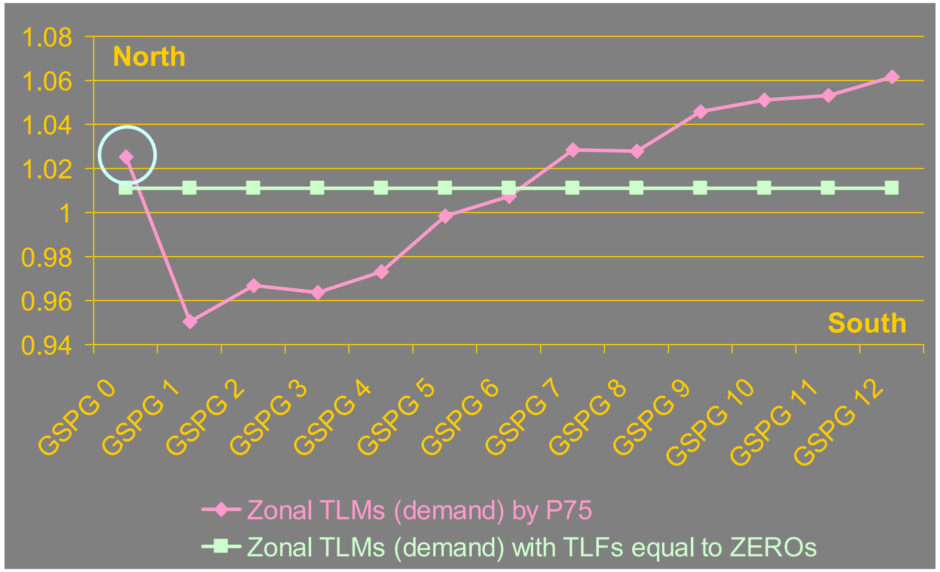

Figure 4: Illustrative example for demand GSPG zonal TLMs in P75

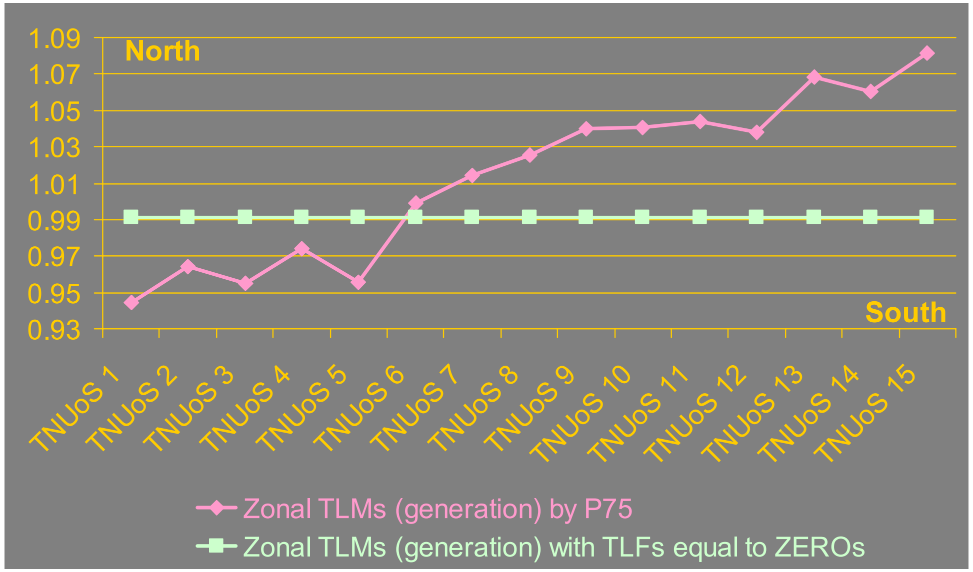

Figure 5: Illustrative example for generation TNUoS zonal TLMs in P75

Introduction of P75 would result in variable zonal TLMs across country.

In calculation of baseline TLFs and TLMs the following Settlement Periods were considered (with their respective indicative networks, **Table 3**):

- 02 January 2002, Settlement Period 36 (peak);
- 01 August 2001, Settlement Period 8 (trough);
- 10 October 2001, Settlement Period 25 (weekday, daylight);
- 11 October 2001, Settlement Period 11 (weekday, night);
- 13 October 2001, Settlement Period 25 (weekend, daylight); and
- 14 October 2001, Settlement Period 11 (weekend, night).

Based on the above characteristic Settlement Periods, **Figure 6** and **Figure 7** present spatial and time variations of zonal TLMs for demand (GSPG zones) and generation (TNUoS (gen) zones). Note that maximal TLM values (or minimal TLM values) do not all belong to the same Settlement Period. The overall indicative variation in zonal TLMs is between 0.95 and 1.065 for demand and between 0.94 and 1.09 for generation.

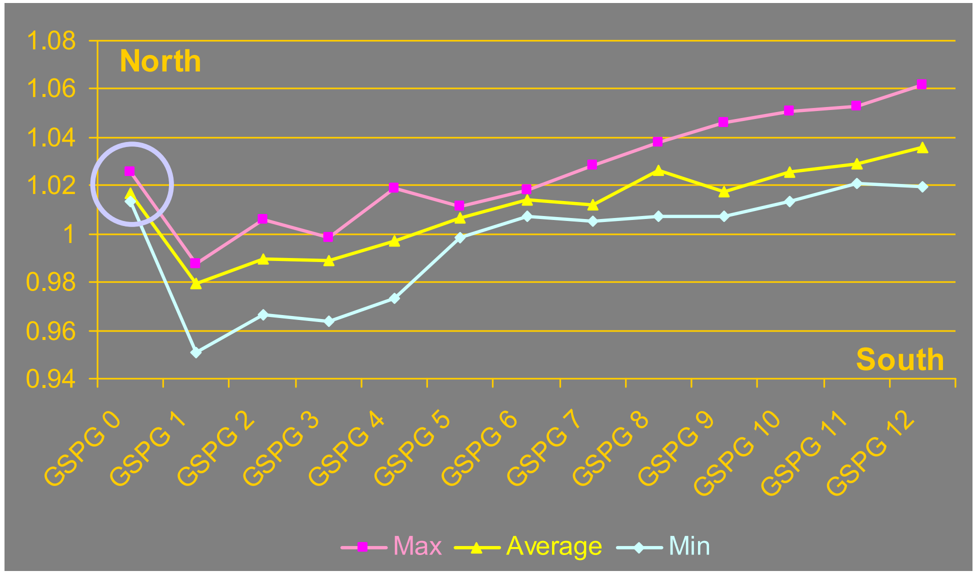

Figure 6: Demand TLMs for P75 (based on marginal, GSPG zone, ½ h TLFs)

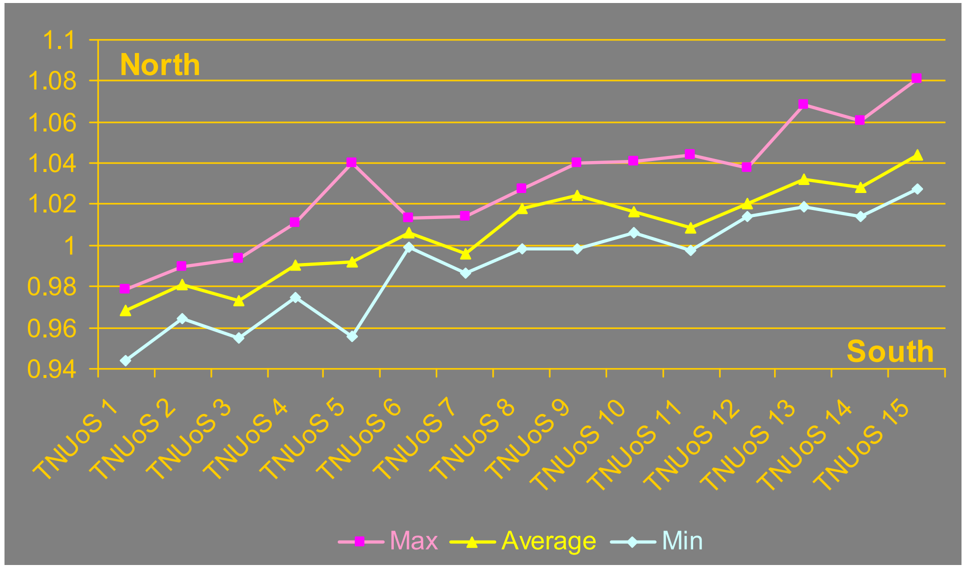

Figure 7: Generation TLMs for P75 (based on marginal, TNUoS (gen) zone, ½ h TLFs)

Introduction of P75 would result in variable zonal TLMs across country and over time.

GSPG Zonal TLMs for demand and TNUoS (gen) Zonal TLMs for generation for the peak (02 January 2002 SP36) and the trough (01 August 2001, SP8) are presented in **Table 6** and **Table 7** respectively.

Table 6: GSPG Zonal TLMs (for demand) for peak and trough Settlement Periods

GSPG Zone	02-Jan-02	01-Aug-01
	SP36	SP8
GSPG 0	1.02548	1.01557
GSPG 1	0.95076	0.98276
GSPG 2	0.96663	1.00608
GSPG 3	0.96394	0.99801
GSPG 4	0.97342	1.01860
GSPG 5	0.99868	1.01108
GSPG 6	1.00719	1.01783
GSPG 7	1.02860	1.00733
GSPG 8	1.02813	1.00744
GSPG 9	1.04604	1.01149
GSPG 10	1.05103	1.01646
GSPG 11	1.05314	1.02107
GSPG 12	1.06172	1.01970

Table 7: TNUoS (gen) Zonal TLMs (for generation) for peak and trough Settlement Periods

TNUoS Zone	02-Jan-02	01-Aug-01
	SP36	SP8
TNUoS 1	0.94433	0.96907
TNUoS 2	0.96427	0.98968
TNUoS 3	0.95527	0.99334
TNUoS 4	0.97430	1.01058
TNUoS 5	0.95585	1.03984
TNUoS 6	0.99934	1.01341
TNUoS 7	1.01437	0.99319
TNUoS 8	1.02545	0.99830
TNUoS 9	1.03982	0.99862
TNUoS 10	1.04084	1.00621
TNUoS 11	1.04374	0.99952
TNUoS 12	1.03793	1.01507
TNUoS 13	1.06809	1.02157
TNUoS 14	1.06025	1.01663
TNUoS 15	1.08130	1.02711

6.1.2 Task 2: Variability of TLFs and TLMs

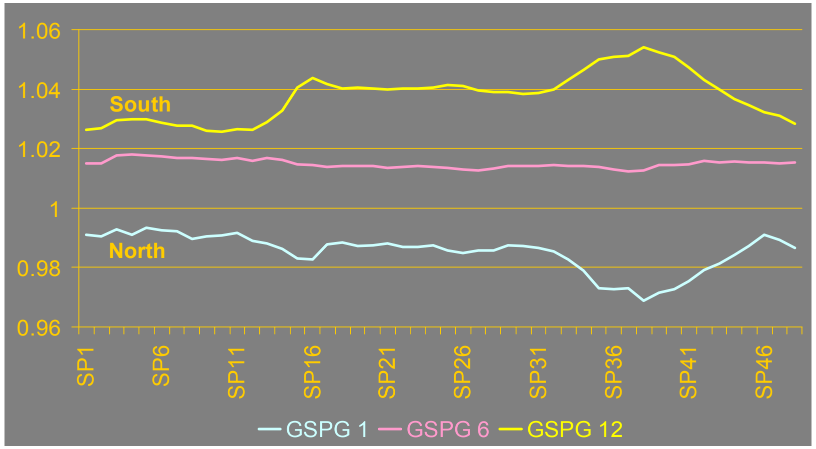

Figure 8: GSPG zone TLMs over a day (10 October 2002) - Demand

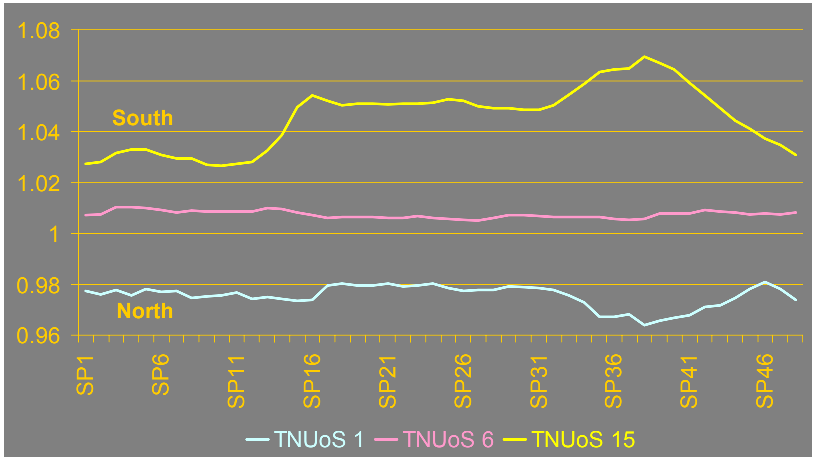

Figure 9: TNUoS (gen) zone TLMs over a day (10 October 2002) - Generation

This task was concerned with variability of TLFs and TLMs over time, and in particular with variability of zonal TLMs over time. The Settlement Periods considered were:

- 02 January 2002, Settlement Periods 8 & 36 (peak day);
- 01 August 2001, Settlement Periods 8 & 36 (trough day);
- 10 October 2001, Settlement Periods 1 to 48 (weekday);
- 11 October 2001, Settlement Period 11 (weekday, night);
- 13 October 2001, Settlement Period 25 (weekend, daylight); and
- 14 October 2001, Settlement Period 11 (weekend, night).

For the above Settlement Periods the zonal minimal and maximal TLMs remained as in Task 1, as presented in **Figure 6** and **Figure 7** (only average values changed). Indicative maximal variability of zonal TLMs, considering each zone individually, was approximately 0.03 for demand and 0.045 for generation (the exception is TNUoS (gen) zone 5, with its reversible hydro plants, where the variation was up to 0.065).

Variations of zonal TLMs over a typical autumn day are presented in **Figure 8**, for demand (GSPG zones), and **Figure 9**, for generation (TNUoS (gen) zones). Each of these figures presents TLMs for three zones, one in the far north, one in far south and one in the middle. The figures represent that not only the zonal TLM values depend, among other factors, on location but, also, that TLM variability, among other factors, depend on location.

The values of zonal TLMs, as well as their variability, depend, among other factors, on location.

6.1.3 Task 3: Sensitivity of TLMs and TLMs to Network Configuration

Due to planned outages, forced outages and reasons such as system stability, system security and system operation optimisation, the configuration of transmission network changes over time. This task was concerned with the effect of network configuration on TLMs. The following Settlement Periods were considered:

- 02 January 2002, Settlement Period 36 (peak);
- 01 August 2001, Settlement Periods 8 (trough);
- 10 October 2001, Settlement Period 25 (weekday daylight);
- 11 October 2001, Settlement Period 11 (weekday, night);
- 13 October 2001, Settlement Period 25 (weekend, daylight); and
- 14 October 2001, Settlement Period 11 (weekend, night).

Zonal TLFs and TLMs were calculated for each of the above Settlement Periods when applied to ***(a)*** intact network and ***(b)*** representative network (these networks are described in section 2.2 of this report). The results were compared with the corresponding results obtained in Task 1 (Baseline TLFs and TLMs – Section 5.1.1 of this report). Six figures in this section, **Figure 10** to **Figure 15** present comparison of demand and generation zonal TLMs from described calculations for 20 January 2002 (peak), 01 August 2001 (trough) and 10 October 2001 Settlement Periods respectively.

From these figures it can be observed that network configuration can have an effect on TLMs:

- while there is almost no difference between intact and representative networks,
- there is a tangible difference between indicative and intact networks.

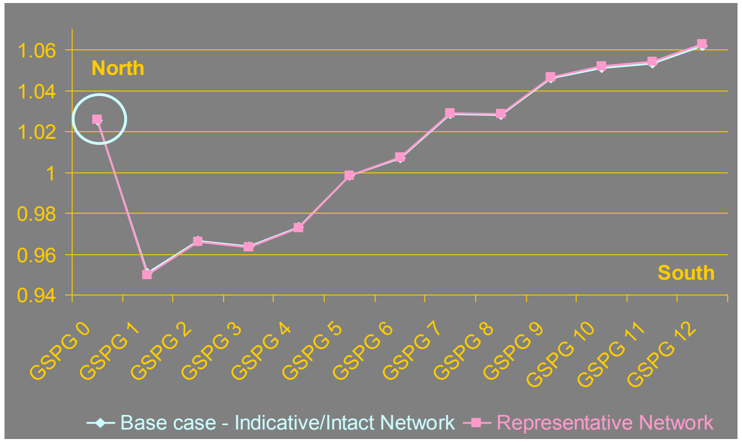

Figure 10: GSPG zone TLMs – Demand (02 January 2002, peak)

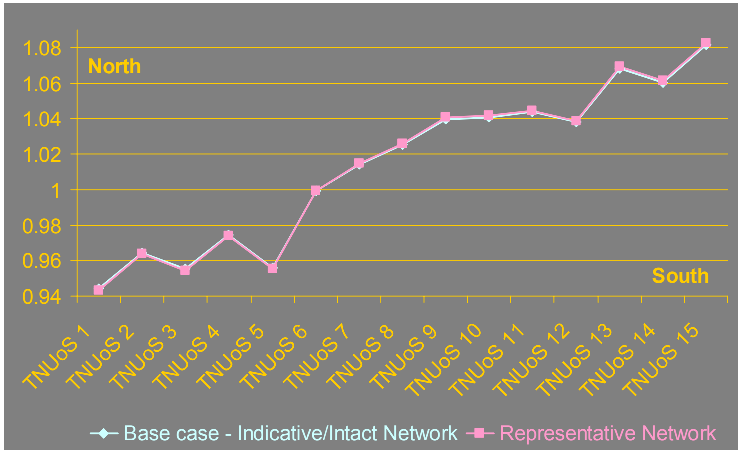

Figure 11: TNUoS (gen) zone TLMs – Generation (02 January 2002, peak)

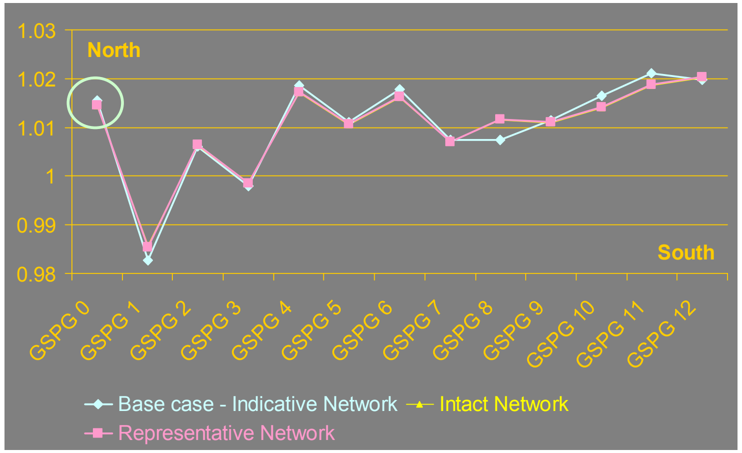

Figure 12: GSPG zone TLMs – Demand (01 August 2001, trough)

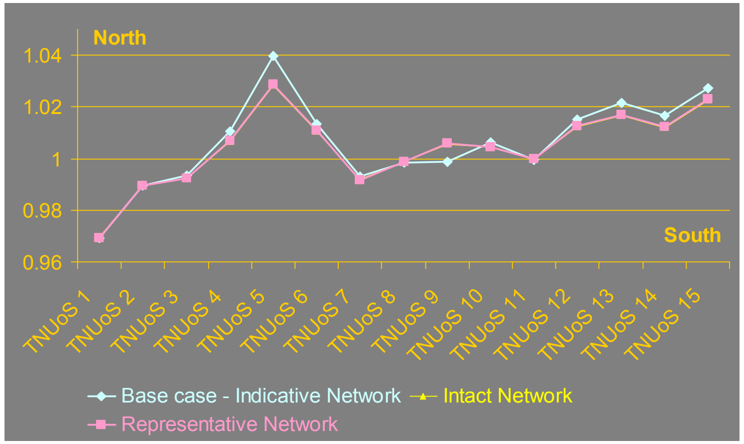

Figure 13: TNUoS (gen) zone TLMs – Generation (01 August 2001, trough)

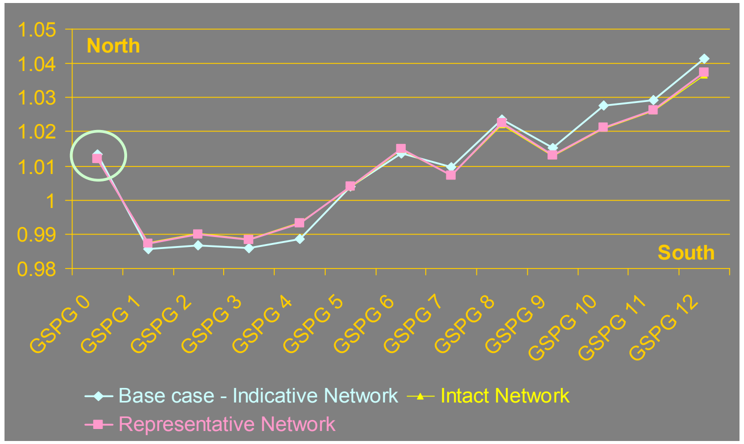

Figure 14: GSPG zone TLMs – Demand (10 October 2001, Weekday daylight)

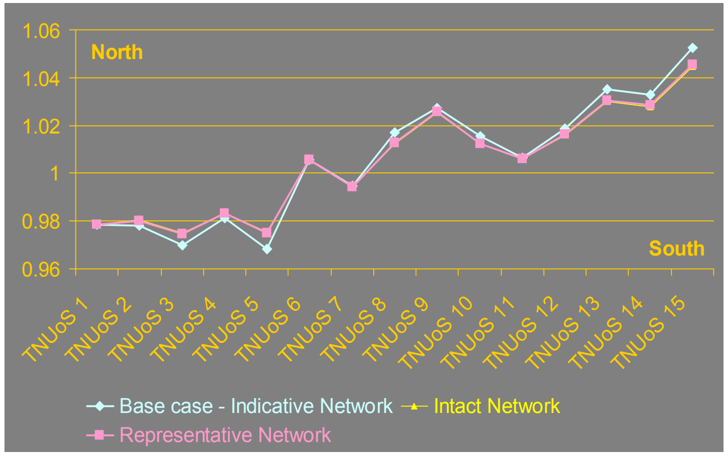

Figure 15: TNUoS (gen) zone TLMs – Generation (10 October 2001, Weekday daylight)

Network configuration can have an effect on TLMs – there is a tangible difference between indicative and intact networks.

6.1.4 Task 4: Sensitivity of TLFs and TLMs to the Inclusion of Constraints in the Calculation Methodology

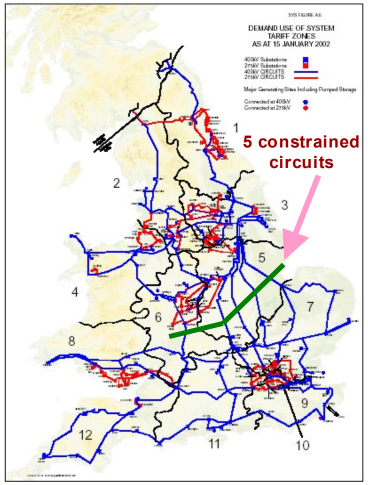

Figure 16: Five double circuits constrained to 80% of the flow in the baseline case for 02 January 2002, SP 36

In the baseline case for 02 January 2002 (Settlement Period 36) for the five double circuits, indicated in **Figure 16**, a constraint was imposed at 80% of the flows calculated for the baseline case demand and generation. In this simple exercise the generation was rescheduled by smearing the imbalances proportionally north and south of the constraint. The overall heating losses dropped from 758.5MW (in the baseline case) to 573MW. The zonal TLMs were compared between the baseline case and this constrained case. The results are presented in **Figure 17** (for demand) and **Figure 18** (for generation) where it can be observed that constrains may have an impact on TLMs.

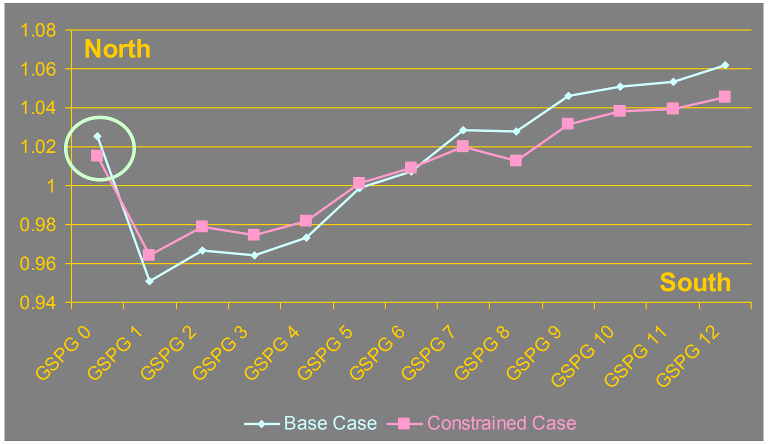

Figure 17: GSPG zone TLMs – Demand (sensitivity to constraints on 02 January 2002, peak)

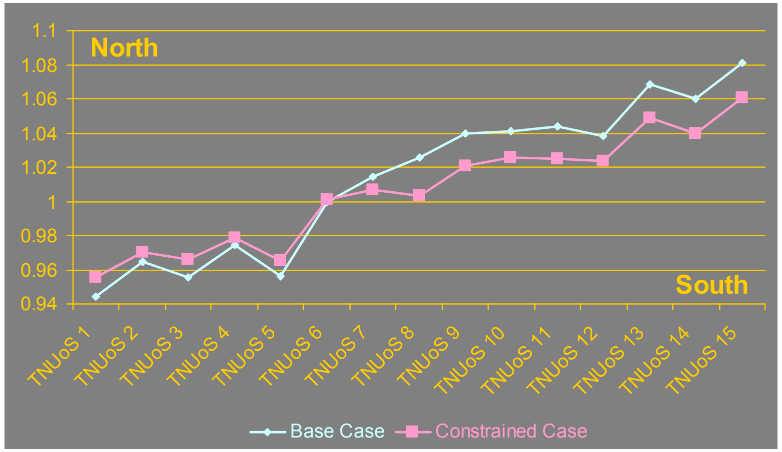

Figure 18: TNUoS zone TLMs – Generation (sensitivity to constraints on 02 January 2002, peak)

Constraints may have an impact on TLMs.

6.1.5 Task 5: Comparison of 'Generation' TLFs/TLMs and 'Demand' TLFs/TLMs at the Same Node

This task was set to compare TLFs and TLMs calculated for generation to those calculated for demand at the same node. This comparison aimed at identifying any cases where a matched pair of generator and consumer in the same location would have an incentive to artificially increase (or decrease) gross exports and imports whilst leaving the net position unchanged.

Tests clearly confirmed the expectation that nodal TLFs (unique for both generation and demand at a node) would not give any such an incentive. In the way nodal TLMs are calculated and in that they are different for generation and demand, they represent loss allocation coefficients, which would potentially provide such an incentive. In a way zonal TLMs depart even further from the nodal TLFs and potentially increase such an incentive. These observations are independent from particular Modification Proposals considered in this project.

Modification Proposal P75 proposes different zones for generation (TNUoS (gen) zones) and demand (GSPG zones). Changing this scheme so that both generation and demand are in the same zones (for example putting then into GSPG zones) would change values of zonal TLFs/TLMs. Examining potential detailed effects of an incentive to artificially increase (or decrease) gross exports and imports whilst leaving the net position unchanged under such a change implies a comprehensive and computationally intensive study. Under the very short time schedule of the project a simple, indicative approach was adopted, that of examining nodes with both generation and demand (Table 8). From a very limited number of such nodes (10 of 386 for case of 02 January 2002, peak) the following twin nodes were chosen:

Node: **Rye House (RYEH11 and RYEH12)**
GSPG zone: **7**
TNUoS (gen) zone: **10**
Settlement Period: **02 January 2002, SP36 (peak)**
At each of the twin nodes: **125.63MW (generation) 159.12MW (demand) (net: 33.49MW demand)**

Table 8: Comparison between nodal TLMs, zonal TLMs (for different generation and demand zones) and zonal TLMs (for unique zoned for generation and demand, GSPG zones)

	Generation	Demand
Nodal TLMs	1.0346	1.0222
TNUoS (for generation) / GSPG (for demand) Zonal TLMs	1.0408	1.0286
GSPG (for generation and demand) Zonal TLMs	1.1005	1.0885

Discrepancies between TLMs for generation and demand at a node are not greatly exacerbated if generation and demand zones are different from one another. However, it should be noted that this example may not be representative.

6.1.6 Task 6: Comparison of 'Nodal' TLFs/TLMs with 'Zonal' TLFs/TLMs

This task was set to compare nodal TLFs with zonal TLFs and nodal TLMs with zonal TLMs with objective to examine how well zonal TLFs/TLMs represent nodal TLFs/TLMs. The following Settlement Periods (with corresponding indicative network data) were considered.

- 02 January 2002, Settlement Period 36 (peak);
- 01 August 2001, Settlement Periods 8 (trough);
- 10 October 2001, Settlement Period 25 (weekday daylight);
- 11 October 2001, Settlement Period 11 (weekday, night);
- 13 October 2001, Settlement Period 25 (weekend, daylight); and
- 14 October 2001, Settlement Period 11 (weekend, night).

Following **Figure 19** to **Figure 26** present comparisons of nodal TLFs/TLMs with zonal TLFs/TLMs for 02 January 2002, Settlement Period 36 (peak) and 01 August 2001, Settlement Periods 8 (trough) respectively.

From the results it can be observed that introduction of Modification Proposal P75 and its zonal TLMs (GSPG zones for demand and TNUoS (gen) zones for generation) would result in nodal TLFs/TLMs for some nodes being closer to neighbouring zonal TLFs/TLMs.

Nodal TLMs for some nodes are closer to neighbouring zonal TLMs.

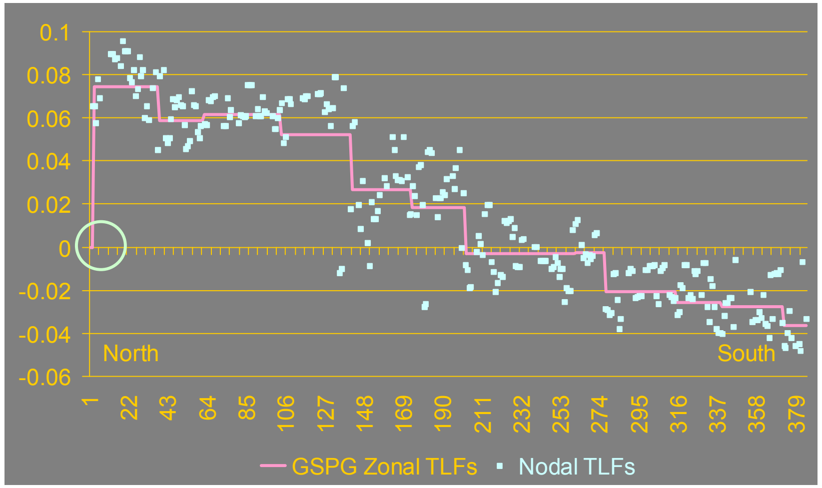

Figure 19: Comparison of Nodal/GSPG zone TLFs – Demand (02 January 2002, peak)

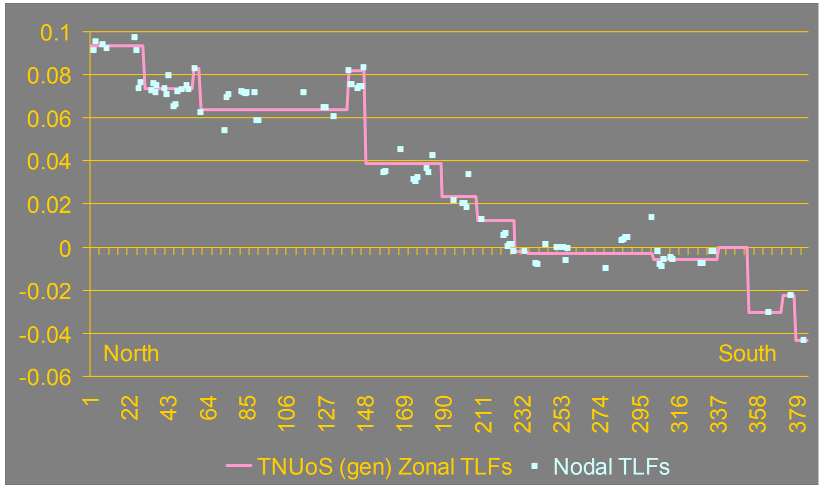

Figure 20: Comparison of Nodal/TNUoS zone TLFs – Generation (02 January 2002, peak)

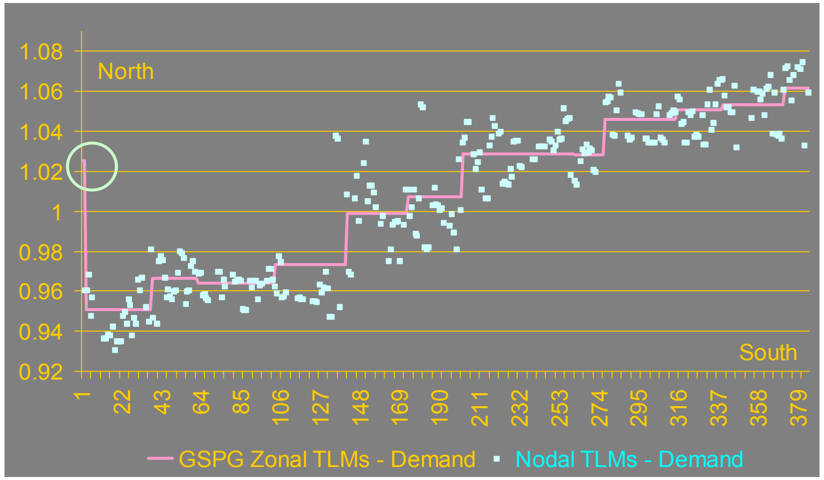

Figure 21: Comparison of Nodal/GSPG zone TLMs – Demand (02 January 2002, peak)

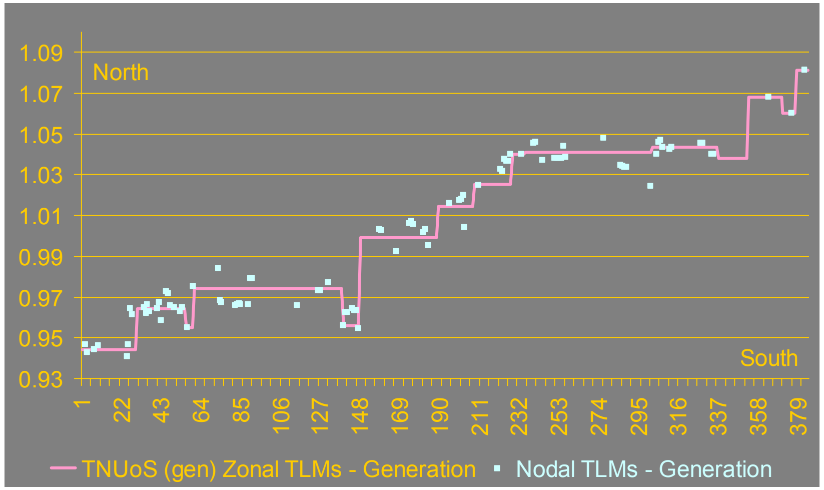

Figure 22: Comparison of Nodal/TNUoS zone TLMs – Generation (02 January 2002, peak)

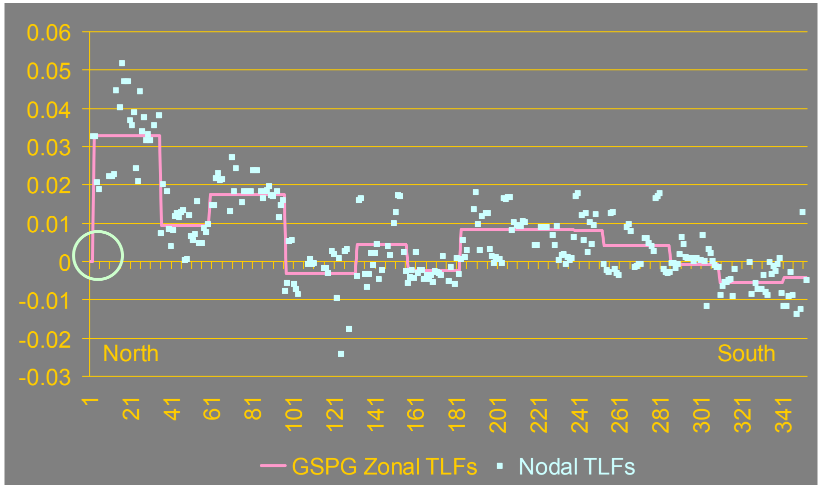

Figure 23: Comparison of Nodal/GSPG zone TLFs – Demand (01 August 2001, trough)

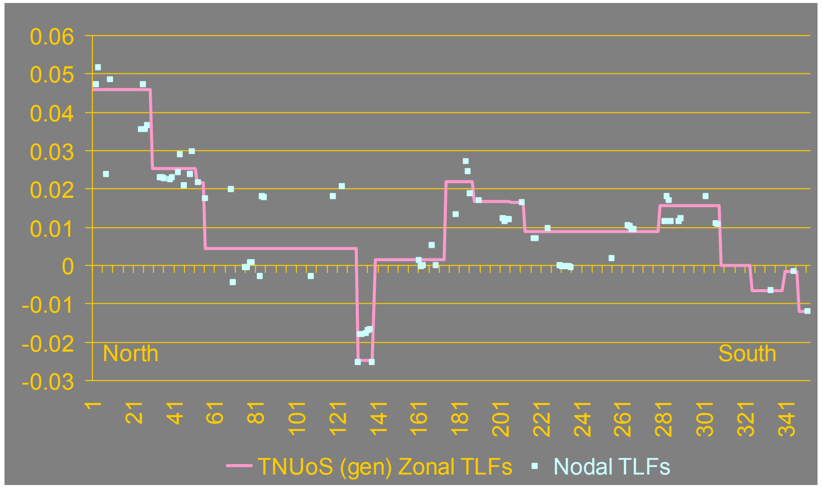

Figure 24: Comparison of Nodal/TNUoS zone TLFs – Generation (01 August 2001, trough)

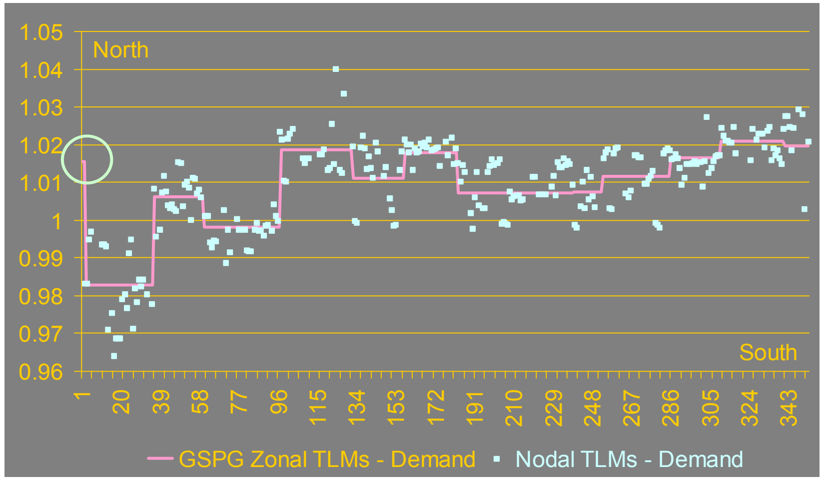

Figure 25: Comparison of Nodal/GSPG zone TLMs – Demand (01 August 2001, trough)

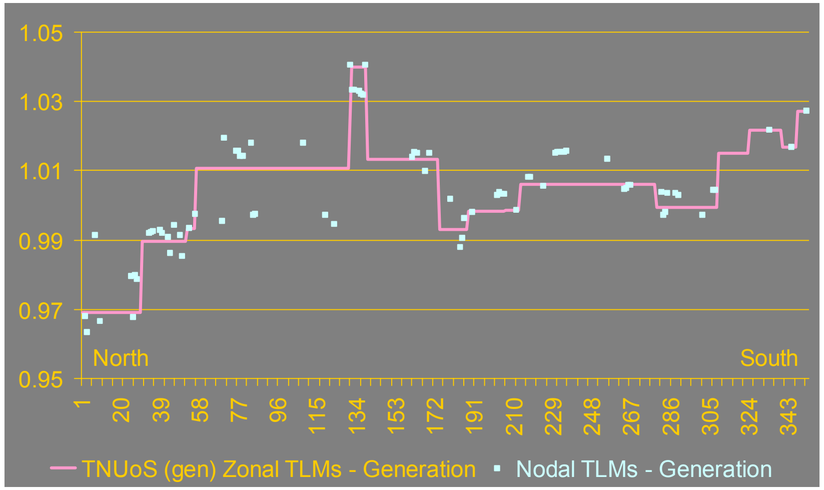

Figure 26: Comparison of Nodal/TNUoS zone TLMs – Generation (01 August 2001, trough)

6.1.7 Task 7: Model Performance Characteristics

This task was set to highlight factors relevant to practical implementation of any modification to allocation of losses based on marginal TLFs. The overall objective was to assist the assessment procedure with regard to practical applicability issues. The following are the points drawn from the experience of exercises performed in this project:

- Data capture depends on capabilities and characteristics of the source systems.
- Data capture will be greatly improved once NGC's state estimator is fully operational. This will reduce data preparation for load flow calculations, reduce the number of necessary assumptions, increase accuracy of calculations and increase the speed of the whole process.
- Amount, duration and quality of data depends on the source systems and the TLF modification chosen.
- The quality and consistency of the data determine the time and effort required to establish acceptable load flow conditions as well as the accuracy of the output values.
- Once a suitable load flow data set has been obtained it should take less than 10 seconds to obtain TLFs for all considered generation/demand points for a Settlement Period.
- The output would be suitably structured list of TLFs.
- Further post processing could be established to automatically produce a higher level of the output data (such as zonal TLMs) if required by the TLF modification chosen.

Once a suitable load flow data set has been established it should take less than 10 seconds to obtain TLFs for all considered generation/demand points for a Settlement Period.

6.1.8 Task 8: Sensitivity to Flows on French Interconnector

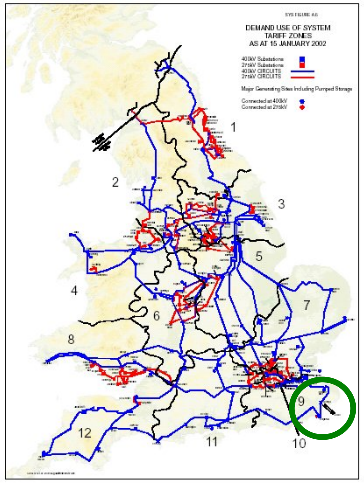

Figure 27: Location of the French inter-connector circuits

In order to examine sensitivity of TLMs to flows on the French inter-connector (**Figure 27**) two Settlement Periods were provided, SP 30 on Wednesday, 31 October 2001 (importing 1355MW) and SP30 on Wednesday, 07 November 2001 (exporting 304MW). The network data used were for 10 October 2001. The total heating losses for 31 October 2001 were 377.1MW and for 07 November 2001 they were 533.3MW.

Zonal TLMs were compared between these two Settlement Periods. The results are presented in **Figure 28** (for demand) and **Figure 29** (for generation).

Flows on French inter-connector may have an impact on TLMs. However, note that the effects in this exercise were complicated as the two compared cases belong to two different days with different demand and generation profiles.

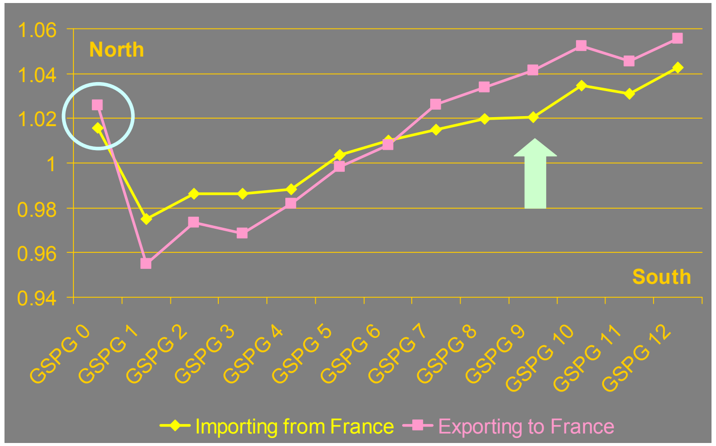

Figure 28: GSPG zone TLMs – Demand (sensitivity to flows on French inter-connector)

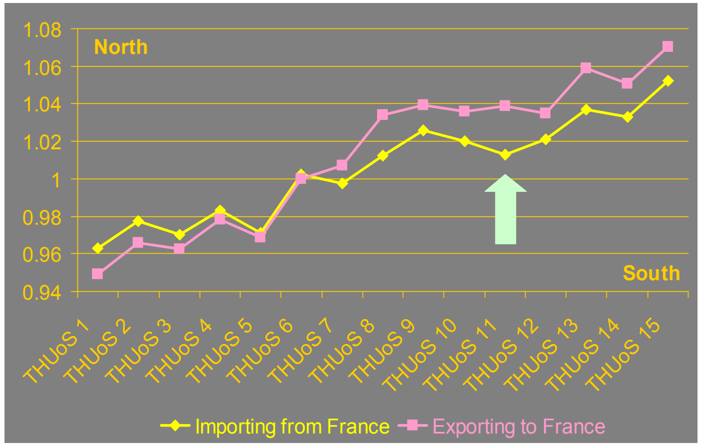

Figure 29: TNUoS zone TLMs – Generation (sensitivity to flows on French inter-connector)

Flows on French inter-connector may have an impact on TLMs.

6.1.9 Tasks 9 & 10: Sensitivity to Breakdown/Withdrawal of Plant and to Participants Responding to Signals

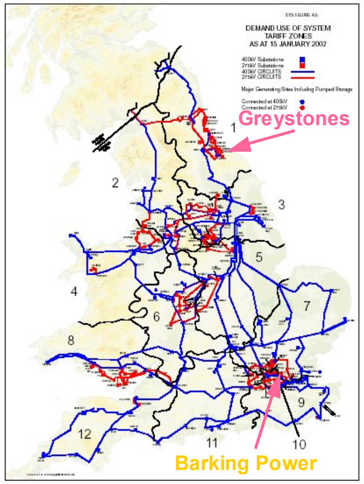

Figure 30: Location of Greystones and Barking Power plants

In order to examine sensitivity of TLMs to breakdown/withdrawal of plant and to participants responding to signals, three cases were designed to be compared with the baseline case for 02 January 2002 (SP36, peak). These three cases were derived from this baseline case so that ***(a)*** 1000MW were removed from Greystones plant (the deficit was supplied by other generators proportionally to their power output), ***(b)*** 1000MW were removed from Barking Power (deficit supplied in the same way) and ***(c)*** 1000MW were moved from Greystones to Barking Power. See location of these two plants in **Figure 30**.

Zonal TLMs were compared between these three cases and with the baseline case. The results are presented in **Figure 31** (for demand) and **Figure 32** (for generation).

Zonal TLMs in Modification Proposal P75 are only locally sensitive to plant breakdown/withdrawal or plat relocation.

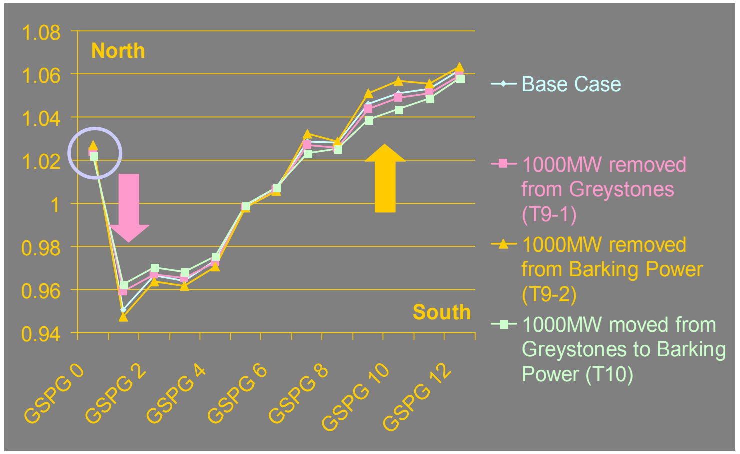

Figure 31: GSPG zone TLMs – Demand (sensitivity to plant outages / response to signals)

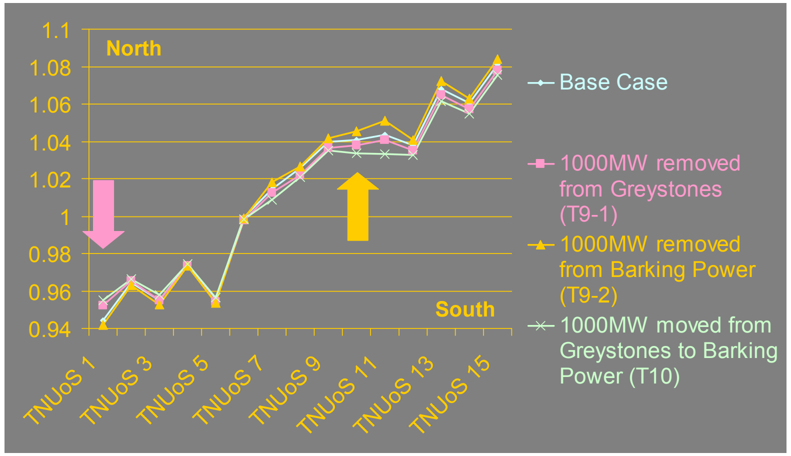

Figure 32: TNUoS zone TLMs – Generation (sensitivity to plant outages / response to signals)

Zonal TLMs in Modification Proposal P75 are only locally sensitive to plant breakdown/removal or plant relocation.

6.1.10 Task 11: Sensitivity to an Increase in Intermittent Generation

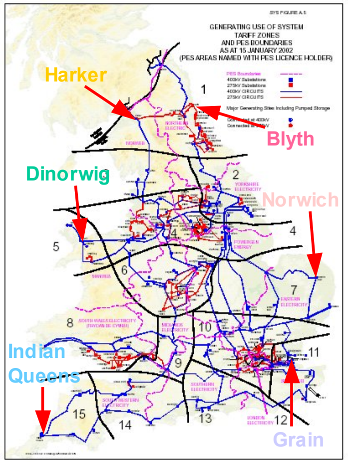

Figure 33: Location of the five alternative sites for intermittent generation replacing in turn power output from Dinorwig

In order to examine sensitivity of TLMs to an increase in intermittent generation five cases were designed to be compared with the baseline case for 02 January 2002 (SP36, peak). These five cases were derived from this baseline case so that 500MW were removed from Dinorwig and were injected in turn at ***(a)*** Blyth, ***(b)*** Harker, ***(c)*** Norwich, ***(d)*** Grain and ***(e)*** Indian Queens. See locations of these sites in **Figure 33**.

Zonal TLMs were compared between these five cases and with the baseline case. The results are presented in **Figure 34** (for demand) and **Figure 35** (for generation).

Zonal TLMs in Modification Proposal P75 are only locally sensitive to intermittent generation.

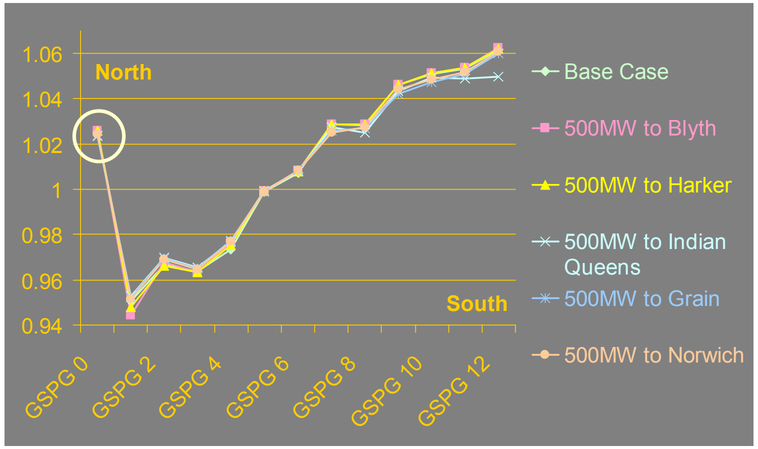

Figure 34: GSPG zone TLMs – Demand (sensitivity to intermittent generation)

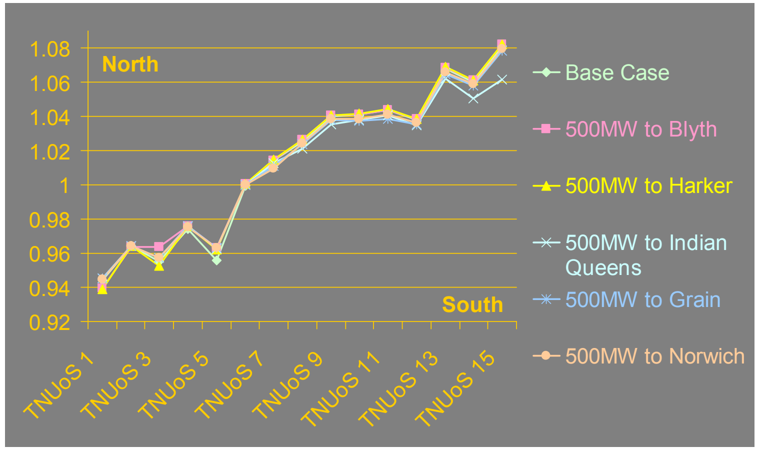

Figure 35: TNUoS zone TLMs – Generation (sensitivity to intermittent generation)

Zonal TLMs in Modification Proposal P75 are only locally sensitive to increase in intermittent generation.

PROJECT RESULTS FOR

MODIFICATION PROPOSAL P82
('INTRODUCTION OF ZONAL TRANSMISSION LOSSES ON AN AVERAGE BASIS')

6.2 Modification Proposal P82 ('Introduction of Zonal Transmission Losses on an Average Basis')

Modification Proposal P82 proposes calculation of zonal ½ h TLMs based on zonal ½ h TLFs, which are based on annual averages of nodal scaled marginal TLFs. The proposed zones are GSPG zones, unique for both demand and generation (**Figure 36**). An additional demand zone, GSPG zone 0 is set specifically for the Scottish inter-connectors (as required by the Terms of Reference). Zonal ½ h TLFs were calculated as average of nodal scaled marginal ½ h TLFs weighted by the sum of absolute values of demand and generation at each node in a zone, for each Settlement Period (½ h) considered. Annual average zonal TLFs were calculated using a time weighted averaging of zonal ½ h TLFs .

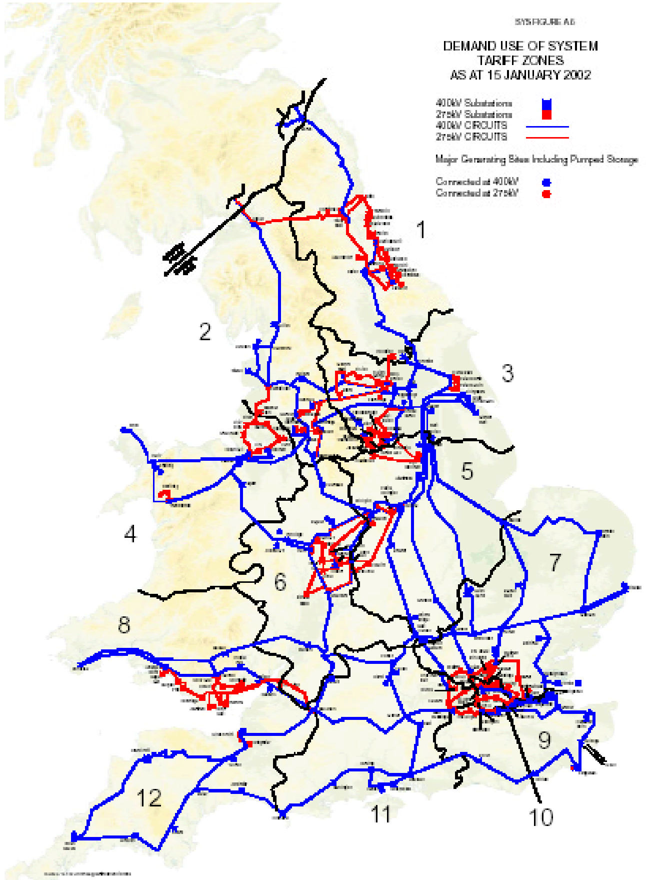

Figure 36: Geographical presentation of GSPG zones used in P82 for both demand and generation

6.2.1 Task 1: Variability of TLFs and Calculation of an Annual Average TLF

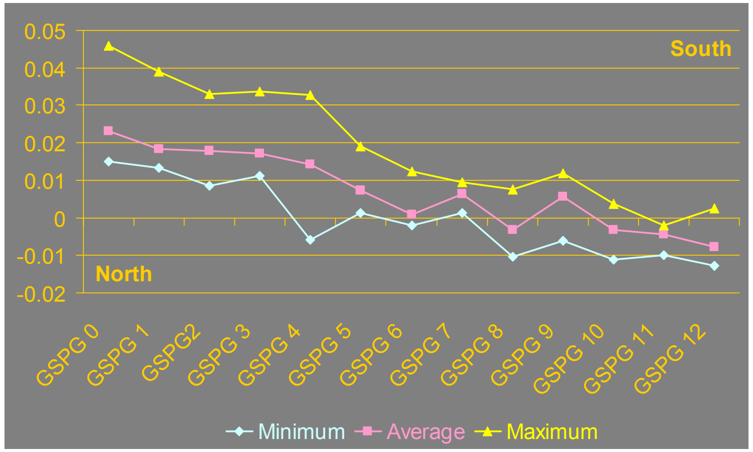

Figure 37: GSPG zone ½ h scaled TLFs over sample time period

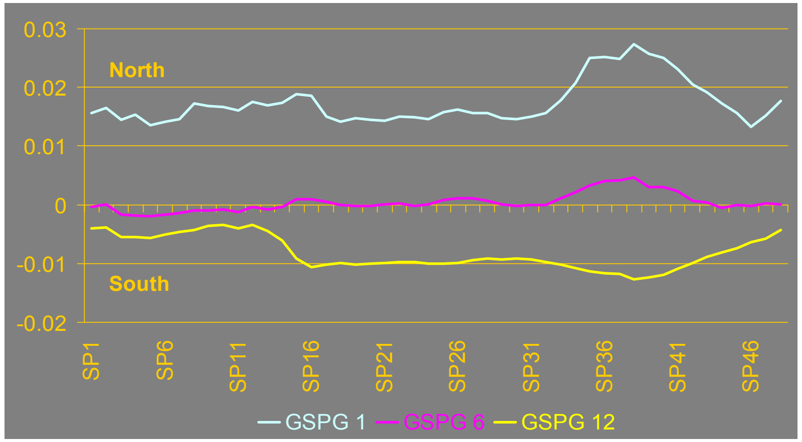

Figure 38: GSPG zone ½ h scaled TLFs over a day (10 October 2002)

This task was concerned with variability of scaled ½ h zonal TLFs over time. The Settlement Periods considered were:

- 02 January 2002, Settlement Periods 8 & 36 (peak day);
- 01 August 2001, Settlement Periods 8 & 36 (trough day);
- 10 October 2001, Settlement Periods 1 to 48 (weekday);
- 11 October 2001, Settlement Period 11 (weekday, night);
- 13 October 2001, Settlement Period 25 (weekend, daylight); and
- 14 October 2001, Settlement Period 11 (weekend, night).

For the above Settlement Periods the GSPG zonal scaled ½ h TLF indicative maximal variability, considering each zone individually, was approximately 0.04 and that was for zone 4, which includes reversible hydro plants (**Figure 37**).

Variations of GSPG zonal scaled ½ h TLFs over a typical autumn day are presented in **Figure 38**. This figure presents TLFs for three zones, one in the far north, one in far south and one in the middle. In this figure TLFs in GSPG zone 1 have the largest variability of about 0.014. Across all GSPG zones the largest variability occurred again in zone 4, and it was about 0.0185. **Figure 38** presents that not only the zonal scaled ½ h TLF values would depend, among other factors, on location but, also, zonal scaled ½ h TLF variability, among other factors, depend on location.

Modification Proposal P82 proposed the use of annual average zonal TLFs in calculation of zonal ½ h TLMs. A set of time weighting coefficients was provided for this purpose related to the above set of Settlement periods (with exception of 11 October 2001, SP11). In the modelling process, initially the time averaging was applied to nodal ½ h TLFs in calculating annual averages of nodal TLFs. These annual averages of nodal TLFs were used to produce ½ h nodal TLMs. The annual averages of nodal TLFs and ½ h nodal TLMs were used in comparison of nodal TLFs/TLMs with zonal TLFs/TLMs (**Figure 50** to **Figure 55**). Subsequently, the time averaging was applied to zonal ½ h TLFs (obtained as average of ½ h nodal TLFs weighted by absolute values of demand and generation at each node in a zone) to produce annual averages of zonal TLFs. These simplify practical P82 application, as there is a single set of zonal TLFs for entire year to be used in calculation of ½ h zonal TLMs.

The values of zonal scaled ½ h TLFs, as well as their variability, would depend, among other factors, on location.

6.2.2 Task 2: Baseline TLFs and TLMs

Currently BSC calculates TLMs with TLFs set to zero. Data for 02 January 2002, Settlement Period 36 (winter peak) were used to illustrate the change P82's TLFs would introduce in calculated zonal TLMs. **Figure 39** presents GSPG zonal TLMs for demand as calculated at present and as they would be calculated by P82. **Figure 40** presents GSPG zonal TLMs for generation as calculated at present and as they would be calculated by P82. GSPG zone 0 is set specifically for the Scottish inter-connectors (as required by the Terms of Reference).

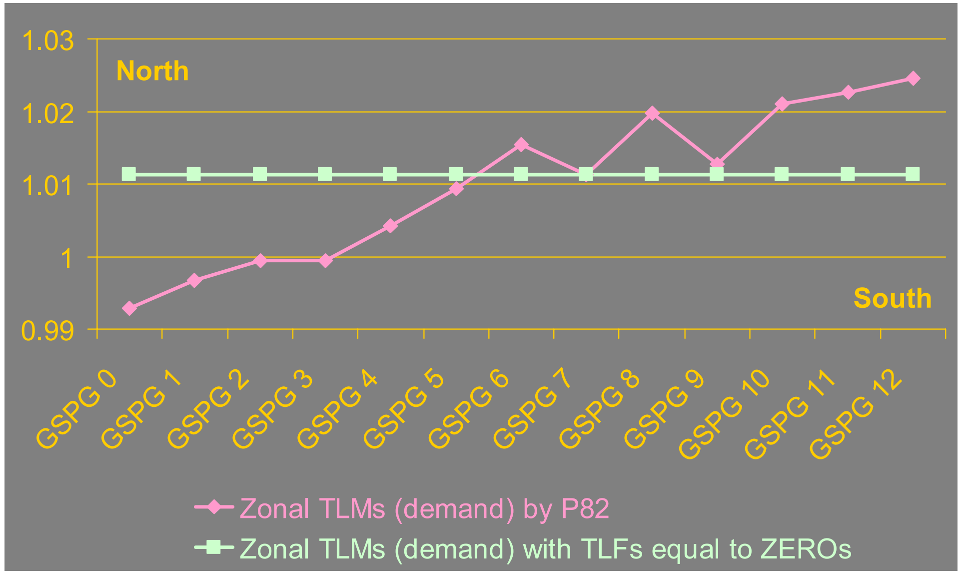

Figure 39: Illustrative example for demand GSPG zonal TLMs in P82

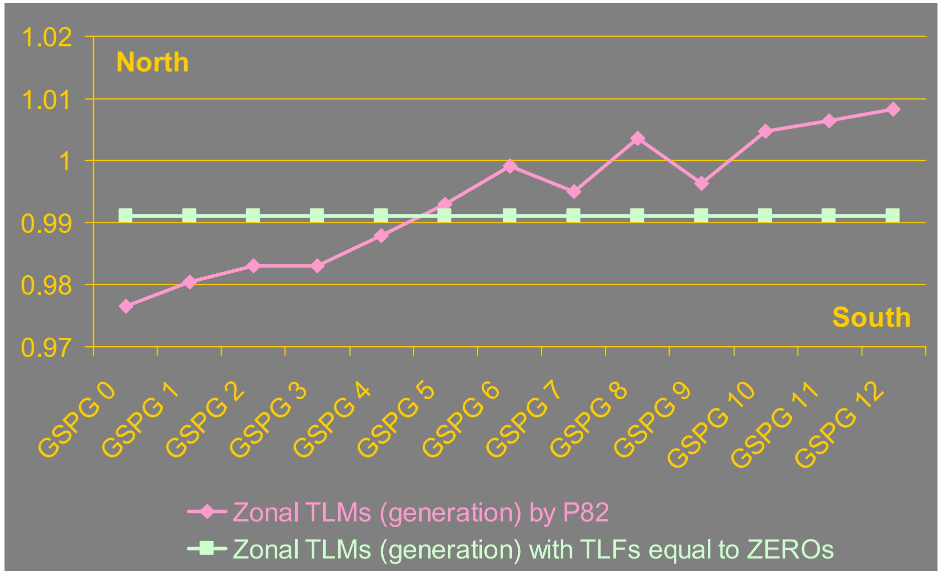

Figure 40: Illustrative example for generation GSPG zonal TLMs in P82

Introduction of P82 would result in variable zonal TLMs across country.

In calculation of baseline TLFs and TLMs the following Settlement Periods were considered (with their respective indicative networks):

- 02 January 2002, Settlement Period 36 (peak);
- 01 August 2001, Settlement Period 8 (trough);
- 10 October 2001, Settlement Period 25 (weekday, daylight);
- 11 October 2001, Settlement Period 11 (weekday, night);
- 13 October 2001, Settlement Period 25 (weekend, daylight); and
- 14 October 2001, Settlement Period 11 (weekend, night).

Based on the above characteristic Settlement Periods, **Figure 41** and **Figure 42** present spatial and time variations of GSPG zonal TLMs for demand and generation respectively. The overall indicative variation in zonal TLMs is between 0.99 and 1.025 for demand and between 0.975 and 1.01 for generation. The use of annual average zonal TLFs would result in relatively small time variations in zonal TLMs. The time variability was 0.0027 for demand zonal TLMs and 0.0014 for generation zonal TLMs and this variability was the same for each zone (i.e. across country).

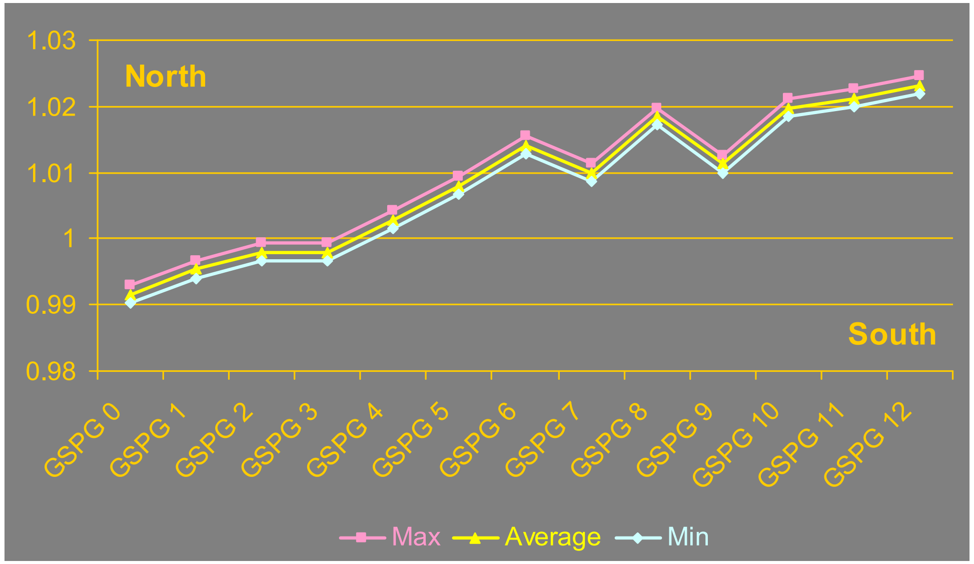

Figure 41: Demand TLMs for P82 (based on scaled, GSPG zone, averaged TLFs)

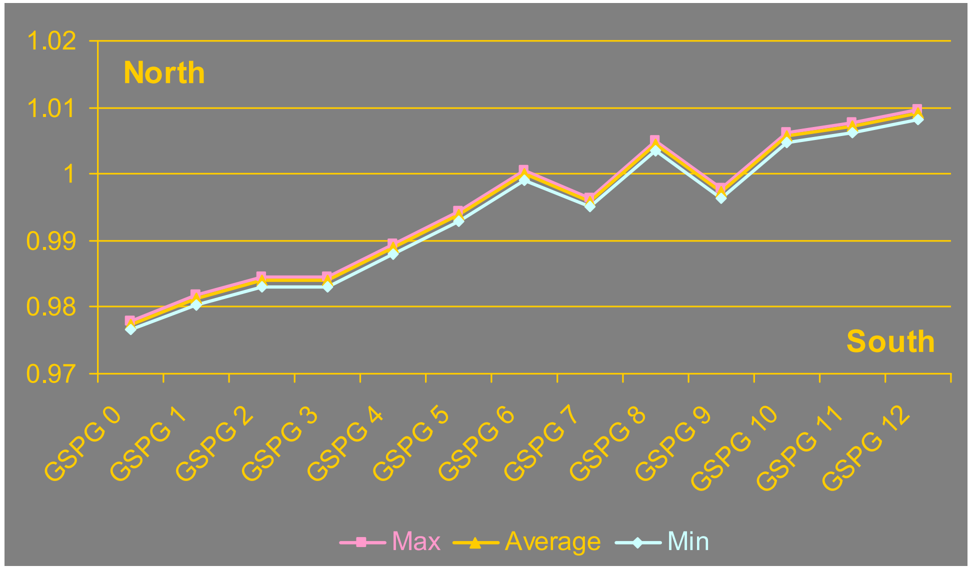

Figure 42: Generation TLMs for P82 (based on scaled, GSPG zone, averaged TLFs)

Introduction of P82 would result in relatively small time variability in zonal TLMs and it would be the same for all zones.

Indicative values from the modelling exercise for GSPG Zonal TLMs for demand and for generation for the peak (02 January 2002 SP36) and the trough (01 August 2001, SP8) are presented in **Table 9** and **Table 10** respectively.

Table 9: GSPG Zonal TLMs (for demand) for peak and trough Settlement Periods

GSPG Zone	02-Jan-02 SP36	01-Aug-01 SP8
GSPG 0	0.99289	0.99196
GSPG 1	0.99676	0.99583
GSPG 2	0.99944	0.99851
GSPG 3	0.99943	0.99850
GSPG 4	1.00428	1.00335
GSPG 5	1.00932	1.00839
GSPG 6	1.01544	1.01451
GSPG 7	1.01135	1.01042
GSPG 8	1.01980	1.01887
GSPG 9	1.01269	1.01176
GSPG 10	1.02108	1.02015
GSPG 11	1.02261	1.02168
GSPG 12	1.02457	1.02364

Table 10: GSPG Zonal TLMs (for generation) for peak and trough Settlement Periods

GSPG Zone	02-Jan-02 SP36	01-Aug-01 SP8
GSPG 0	0.97658	0.97688
GSPG 1	0.98045	0.98074
GSPG 2	0.98314	0.98343
GSPG 3	0.98312	0.98342
GSPG 4	0.98798	0.98827
GSPG 5	0.99301	0.99331
GSPG 6	0.99914	0.99943
GSPG 7	0.99505	0.99534
GSPG 8	1.00349	1.00379
GSPG 9	0.99638	0.99667
GSPG 10	1.00478	1.00507
GSPG 11	1.00631	1.00660
GSPG 12	1.00827	1.00856

6.2.3 Task 3: Variability of TLMs

This task was concerned with variability of TLMs over time. The Settlement Periods considered were:

- 02 January 2002, Settlement Periods 8 & 36 (peak day);
- 01 August 2001, Settlement Periods 8 & 36 (trough day);
- 10 October 2001, Settlement Periods 1 to 48 (weekday);
- 11 October 2001, Settlement Period 11 (weekday, night);
- 13 October 2001, Settlement Period 25 (weekend, daylight); and
- 14 October 2001, Settlement Period 11 (weekend, night).

Figure 43 and **Figure 44** present variations of GSPG zone TLMs for demand and generation respectively, over the sample time (the above Settlement Periods). While variability of zonal TLMs in each zone is very small over time, due to averaging ½ h TLFs, there is a spatial variability. The indicative variability of all zonal TLMs is approximately 0.035 for demand and 0.035 for generation. The temporal variability of zonal TLMs in each zone was identical (due to the use of annual average zonal TLFs) and it was less than 0.003 for demand and less than 0.002 for generation.

Variations of zonal TLMs over a typical autumn day (10 October 2001) are presented in **Figure 45** for demand (GSPG zones) and in **Figure 46** for generation (GSPG zones). Each of these figures presents TLMs for three zones, one in the far north, one in far south and one in the middle. Indicative daily (temporal) variability of zonal TLMs for a typical autumn day (10 October 2001) was identical in each zone (due to the use of annual average zonal TLFs), and was less than 0.0015 for demand and less than 0.001 for generation. With introduction of P82 **Figure 45** and **Figure 46** present that while there would be very little temporal variations in zonal TLMs, the zonal TLM values would depend on location.

Introduction of Modification Proposal P82 would result in very small temporal variations in zonal TLMs, while zonal TLM values would depend on location.

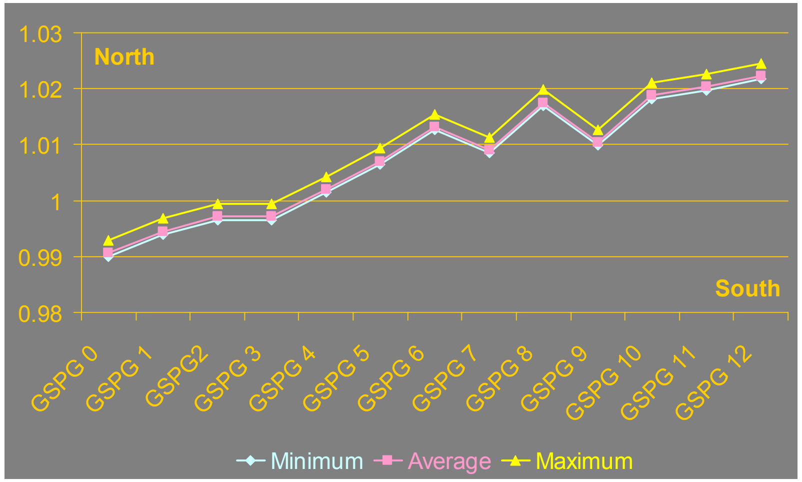

Figure 43: GSPG zone TLMs over sample period - Demand

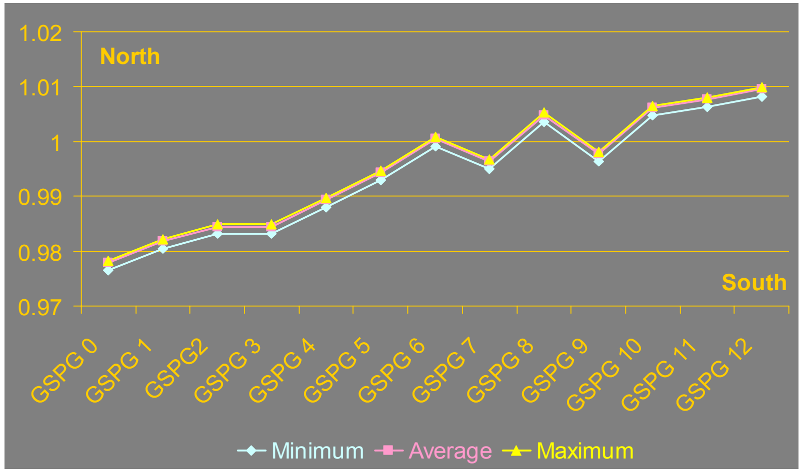

Figure 44: GSPG zone TLMs over sample period - Generation

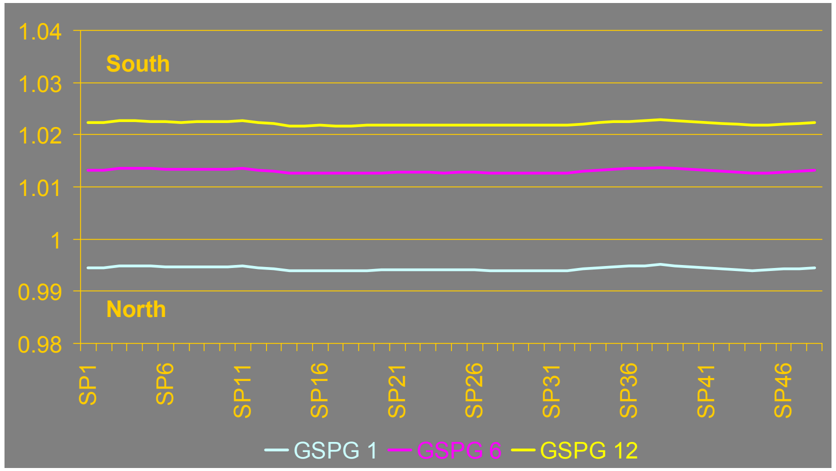

Figure 45: GSPG zone TLMs over a day – Demand (10 October 2001)

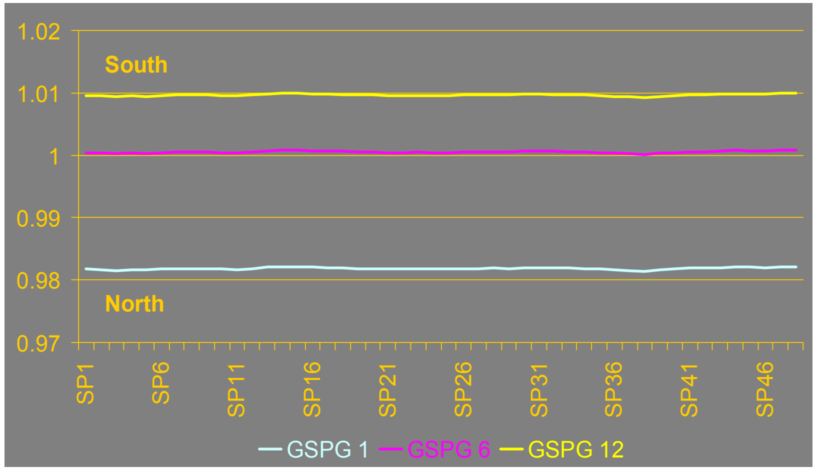

Figure 46: GSPG zone TLMs over a day – Generation (10 October 2001)

Introduction of P82 would result in almost non-existent daily variations in zonal TLMs on a typical autumn day.

6.2.4 Task 4: Sensitivity of TLFs & TLMs to Choice of Historic Data and Weightings

As the required input data were not provided it was agreed that this task would not be required.

6.2.5 Task 5: Sensitivity of TLFs and TLMs to the Inclusion of Constraints in the Calculation Methodology

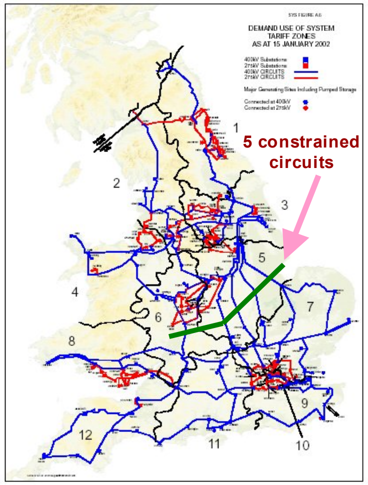

Figure 47: Five double circuits constrained to 80% of the flow in the baseline case for 02 January 2002, SP 36

In the baseline case for 02 January 2002 (Settlement Period 36) for the five double circuits indicated in **Figure 47** a constraint was imposed at 80% of the flows in the baseline case. In this simple exercise the generation was rescheduled by smearing the imbalances proportionally north and south of the constraint. The overall heating losses dropped from 758.5MW (in the baseline case) to 573MW. The GSPG zonal TLMs were compared between the baseline case and this constrained case. The results are presented in **Figure 48** (for demand) and **Figure 49** (for generation).

Zonal TLMs in P82 are almost insensitive to constraints, as the effects of such events would be averaged in the following year.

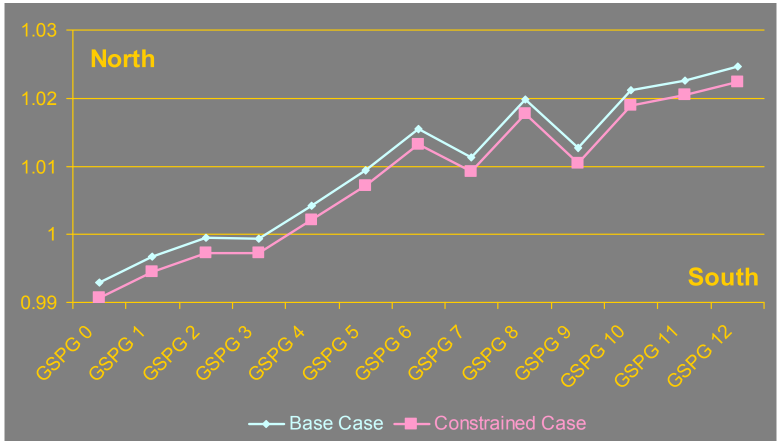

Figure 48: GSPG zone TLMs – Demand (sensitivity to constraints on 02 January 2002, peak)

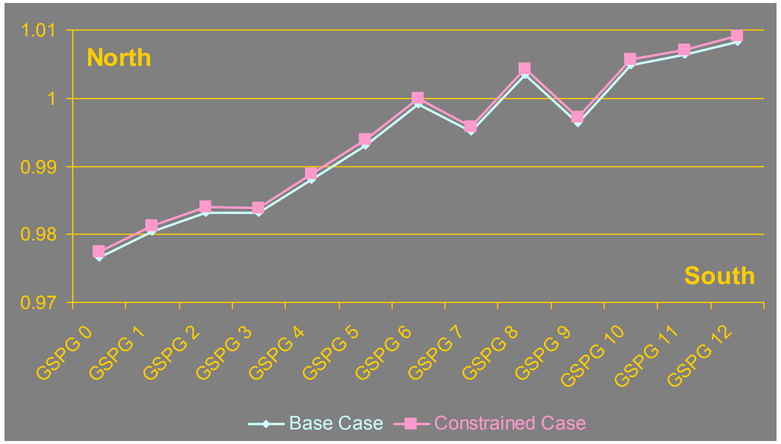

Figure 49: GSPG zone TLMs – Generation (sensitivity to constraints on 02 January 2002, peak)

Zonal TLMs in P82 are almost insensitive to constraints, as the effects of such events would be averaged in the following year.

6.2.6 Task 6: Comparison of 'Nodal' TLFs/TLMs with 'Zonal' TLFs/TLMs

This task was set to compare nodal TLFs with zonal TLFs and nodal TLMs with zonal TLMs with the objective to examine how well zonal TLFs/TLMs represent nodal TLFs/TLMs. The following Settlement Periods (with corresponding indicative network data) were considered.

- 02 January 2002, Settlement Period 36 (peak);
- 01 August 2001, Settlement Periods 8 (trough);
- 10 October 2001, Settlement Period 25 (weekday daylight);
- 11 October 2001, Settlement Period 11 (weekday, night);
- 13 October 2001, Settlement Period 25 (weekend, daylight); and
- 14 October 2001, Settlement Period 11 (weekend, night).

Figure 50 to **Figure 55** present comparisons of nodal TLFs/TLMs with zonal TLFs/TLMs for 02 January 2002, SP 36 (peak) and 01 August 2001, SP 8 (trough) respectively. Note that in P82, zonal TLFs apply equally to demand and generation, while demand zonal TLMs and generation zonal TLMs are different for the same GSPG zones. Also, **Figure 50** and **Figure 51** are practically identical, except for the number of participating nodes (both nodal and zonal TLFs are annual averages). Note that zonal TLFs/TLMs in **Figure 50** to **Figure 55** were not derived directly from respective nodal TLFs/TLMs. Annual average nodal/zonal TLFs are derived from ½ h nodal/zonal TLFs respectively. Nodal/zonal TLMs (they change with change in metered volumes) are derived from annual average nodal/zonal TLFs, respectively.

From the results it can be observed that introduction of Modification Proposal P82 and its zonal TLMs (GSPG zones for both demand and generation) could result in nodal TLFs/TLMs for some nodes being closer to neighbouring zonal TLFs/TLMs.

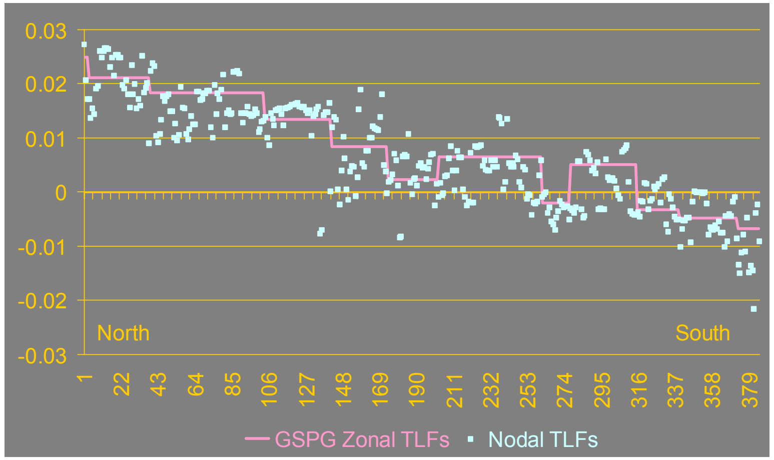

Figure 50: Comparison of Nodal/GSPG zone TLFs (02 January 2002, peak)

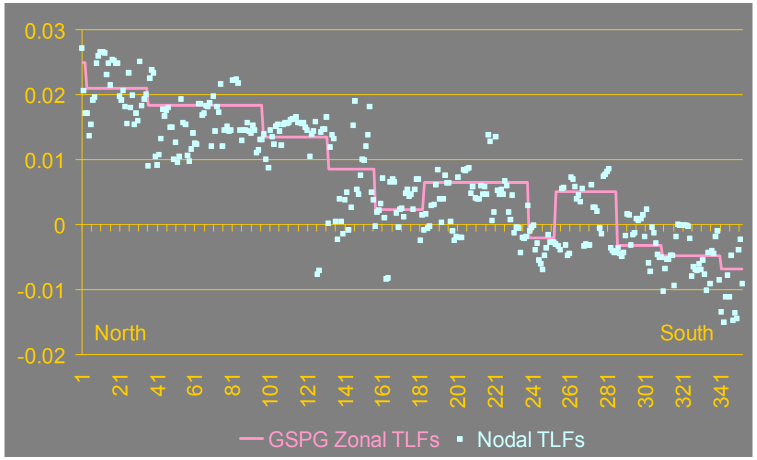

Figure 51: Comparison of Nodal/GSPG zone TLFs (01 August 2001, trough)

Nodal TLFs for some nodes are closer to neighbouring zonal TLFs.

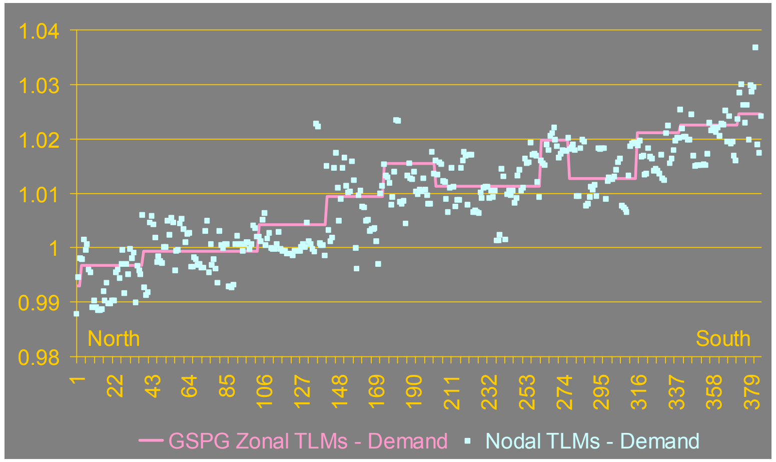

Figure 52: Comparison of Nodal/GSPG zone TLMs – Demand (02 January 2002, peak)

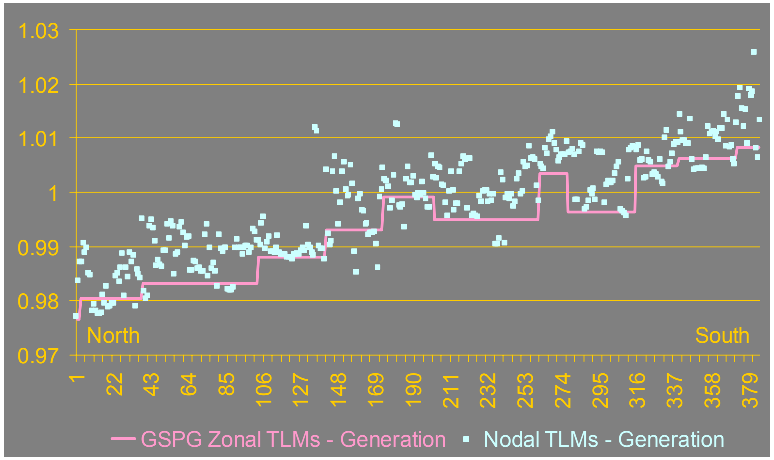

Figure 53: Comparison of Nodal/GSPG zone TLMs – Generation (02 January 2002, peak)

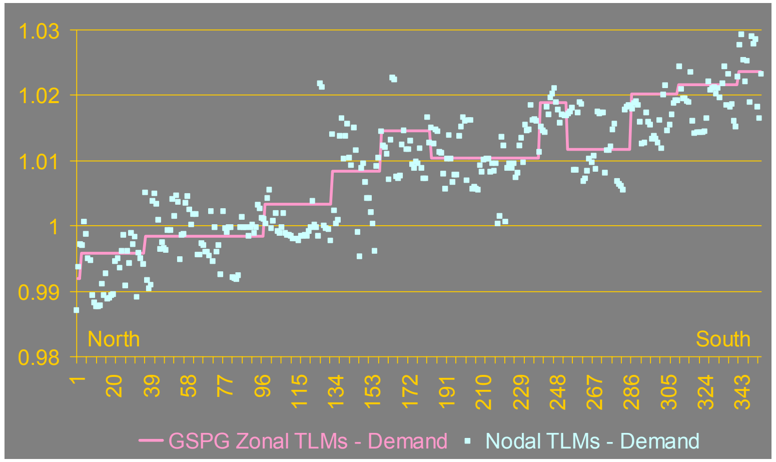

Figure 54: Comparison of Nodal/GSPG zone TLMs – Demand (01 August 2001, trough)

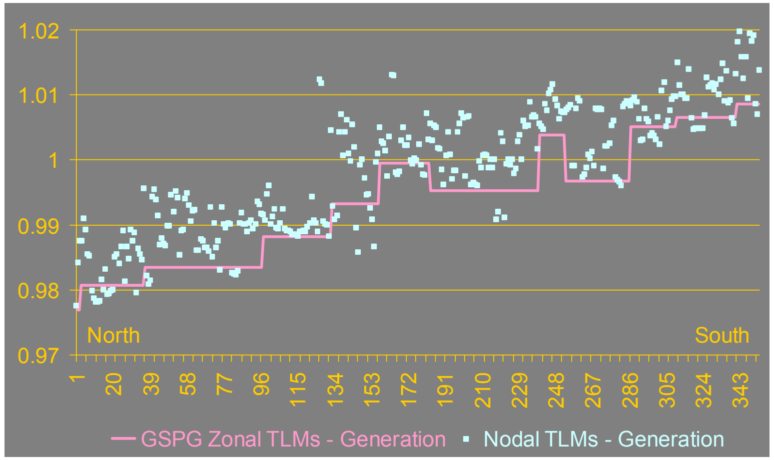

Figure 55: Comparison of Nodal/GSPG zone TLMs – Generation (01 August 2001, trough)

Nodal TLMs for some nodes are closer to neighbouring zonal TLMs.

6.2.7 Task 7: Sensitivity to Flows on French Interconnector

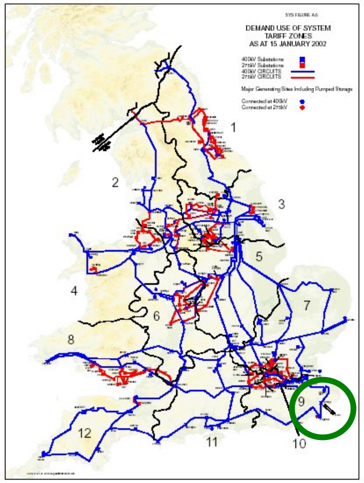

Figure 56: Location of the French inter-connector circuits

In order to examine sensitivity of TLMs to flows on the French inter-connector (**Figure 56**) two Settlement Periods were provided, SP 30 on Wednesday, 31 October 2001 (importing 1355MW) and SP30 on Wednesday, 07 November 2001 (exporting 304MW). The network data used were for 10 October 2001. The total heating losses for 31 October 2001 were 377.1MW and for 07 November 2001 they were 533.3MW.

Zonal TLMs were compared between these two Settlement Periods. The results are presented in **Figure 57** (for demand) and **Figure 58** (for generation).

Zonal TLMs in P82 almost insensitive to flows on French inter-connector – because the effects of such events would be averaged in the following year. However, as a matter of principle, note that the effects in this exercise were complicated as the two compared cases belong to two different days with different demand and generation profiles.

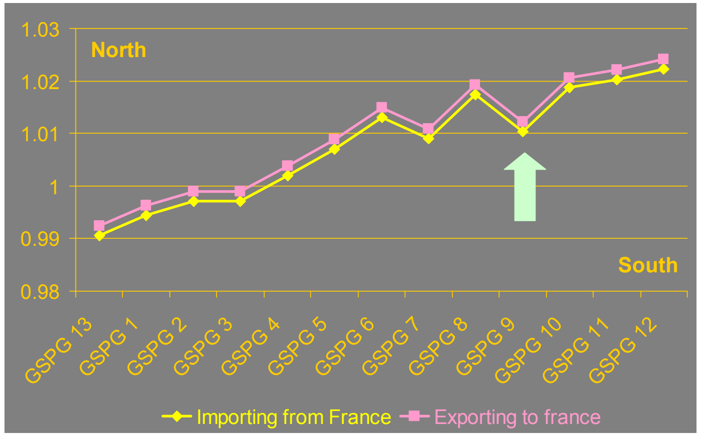

Figure 57: GSPG zone TLMs – Demand (sensitivity to flows on French inter-connector)

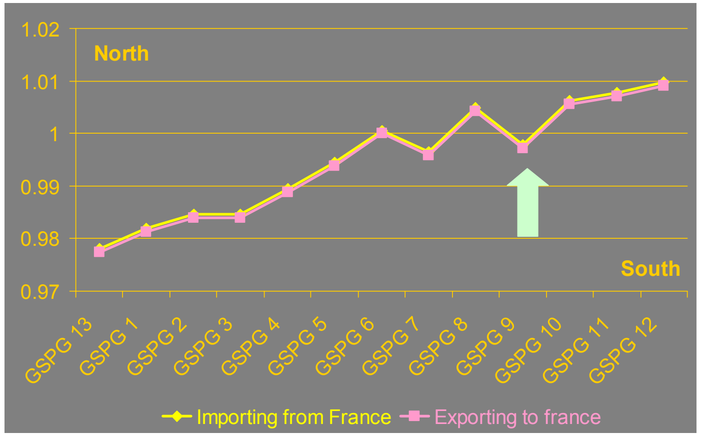

Figure 58: GSPG zone TLMs – Generation (sensitivity to flows on French inter-connector)

TLMs in P82 are almost insensitive to flows on French inter-connector, as the effects of such events would be averaged in the following year.

6.2.8 Task 8: Degree to which a Scaling Factor of 0.5 Recovers Heating Losses

Modification Proposal P82 proposed the use of scaled TLFs and considered application of a constant scaling factor of 0.5. This task considered how well such a constant scaling factor of 0.5 recovers the heating losses.

A constant scaling factor of 0.5 was compared with the accurate scaling factors for the six baseline cases (listed in task 2, section 5.2.2). Accurate scaling factors are such that when used to calculate scaled nodal ½ h TLFs, these TLFs would recover the heating losses precisely. Comparison between scaling factor of 0.5 and accurate scaling factors is presented in **Figure 59**, and comparison how these two kinds of scaling factors recover losses is presented in **Figure 60**.

Scaling factor of 0.5 does not precisely recover heating losses but it appears to be a reasonable approximation. It should be noted that application of accurate scaling factors is computationally trivial.

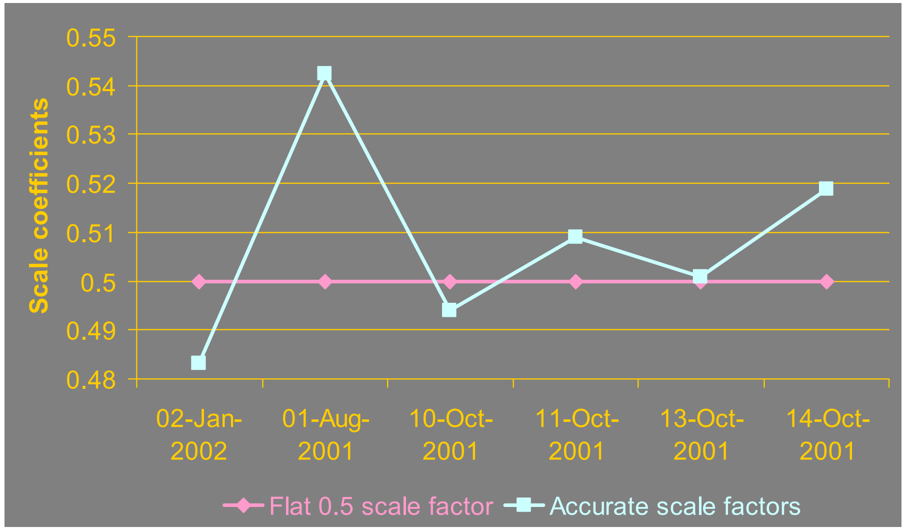

Figure 59: Comparison between flat 0.5 scaling factor for TLFs and the accurate scaling factors

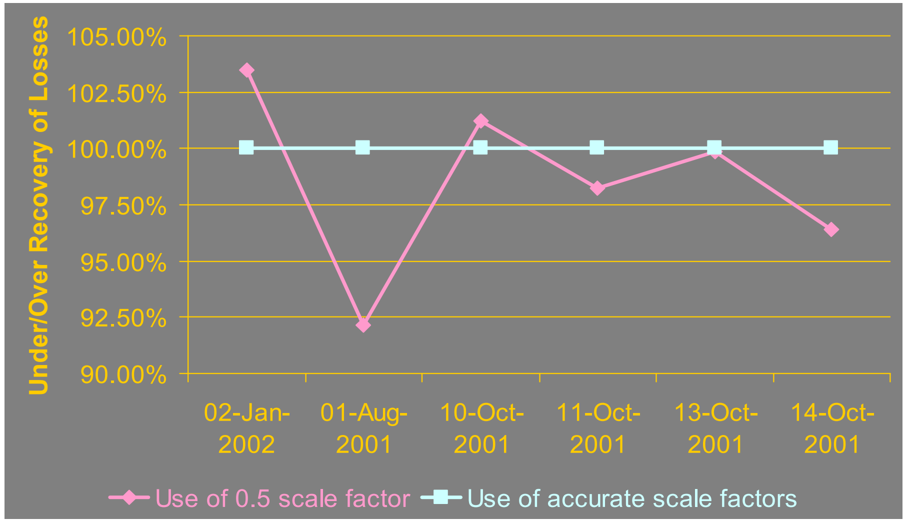

Figure 60: Recovery of heating losses with scaling factor 0.5 and with accurate scaling factors

Scaling factor of 0.5 does not precisely recover heating losses but it appears to be a reasonable approximation.

6.2.9 Tasks 9 & 10: Sensitivity to Breakdown/Withdrawal of Plant and to Participants Responding to Signals

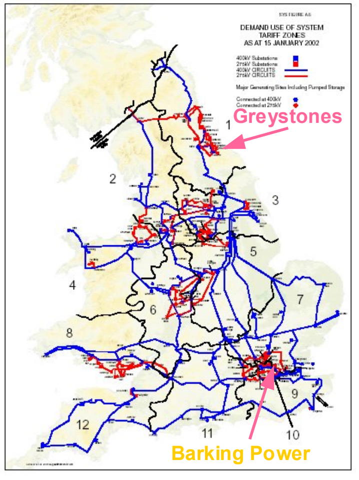

Figure 61: Location of Greystones and Barking Power plants

In order to examine sensitivity of TLMs to breakdown/withdrawal of plant and to participants responding to signals, three cases were designed to be compared with the baseline case for 02 January 2002 (SP36, peak). These three cases were derived from this baseline case so that ***(a)*** 1000MW were removed from Greystones plant (the deficit was supplied by other generators proportionally to their power output), ***(b)*** 1000MW were removed from Barking Power (deficit supplied in the same way) and ***(c)*** 1000MW were moved from Greystones to Barking Power. See location of these two plants in **Figure 61**.

Zonal TLMs were compared between these three cases and with the baseline case. The results are presented in **Figure 62** (for demand) and **Figure 63** (for generation).

Zonal TLMs in Modification Proposal P82 are almost insensitive to plant breakdown/withdrawal or plat relocation – because the effects of such events would be averaged in the following year.

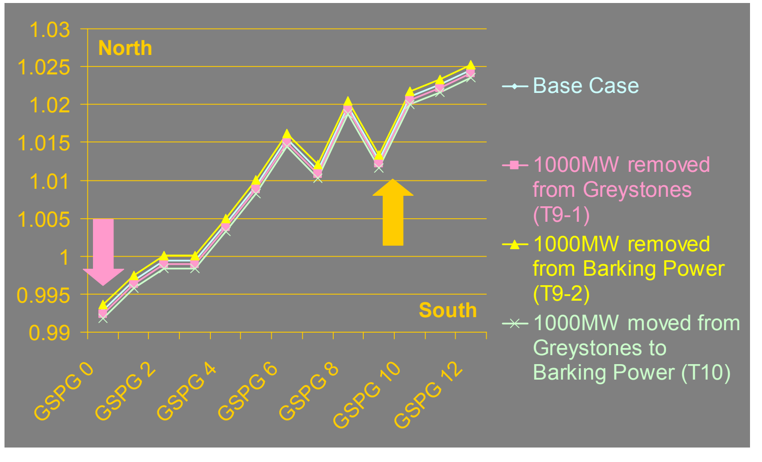

Figure 62: GSPG zone TLMs – Demand (sensitivity to plant outages / response to signals)

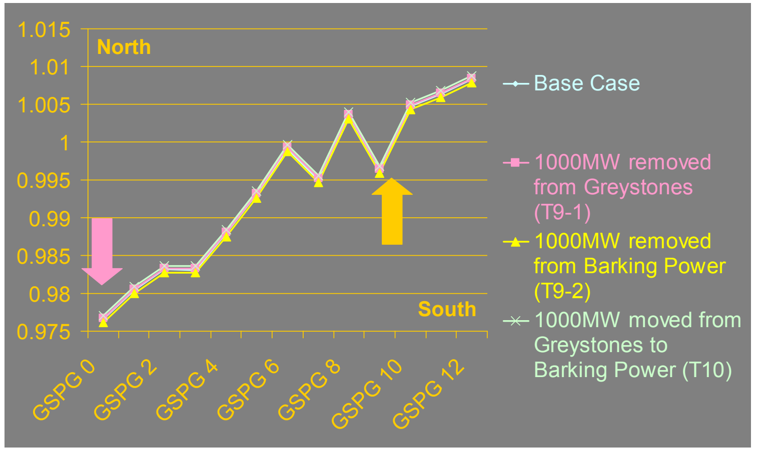

Figure 63: GSPG zone TLMs – Generation (sensitivity to plant outages / response to signals)

TLMs in P82 are almost insensitive to plant breakdown/removal or plant relocation, as the effects of such events would be averaged in the following year.

6.2.10 Task 11: Sensitivity to an Increase in Intermittent Generation

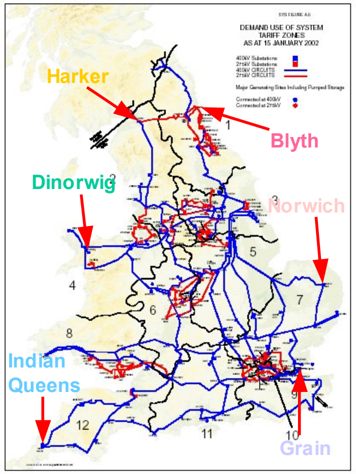

Figure 64: Location of the five alternative sites for intermittent generation replacing in turn power output from Dinorwig

In order to examine sensitivity of TLMs to an increase in intermittent generation five cases were designed to be compared with the baseline case for 02 January 2002 (SP36, peak). These five cases were derived from this baseline case so that 500MW were removed from Dinorwig and were injected in turn at ***(a)*** Blyth, ***(b)*** Harker, ***(c)*** Norwich, ***(d)*** Grain and ***(e)*** Indian Queens. See locations of these sites in **Figure 64**.

Zonal TLMs were compared between these five cases and with the baseline case. The results are presented in **Figure 65** (for demand) and **Figure 66** (for generation).

Zonal TLMs in Modification Proposal P82 are almost insensitive to an increase in intermittent generation – because the effects of such events would be averaged in the following year.

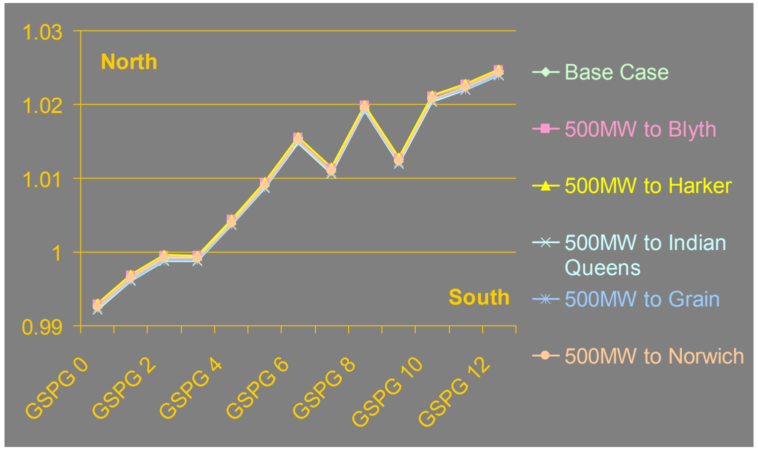

Figure 65: GSPG zone TLMs – Demand (sensitivity to intermittent generation)

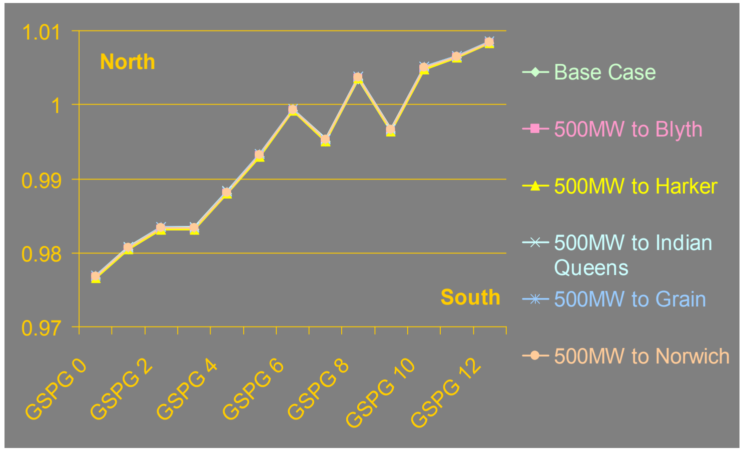

Figure 66: GSPG zone TLMs – Generation (sensitivity to intermittent generation)

TLMs in P82 are almost insensitive to an increase in intermittent generation, as the effects of such events would be averaged in the following year.