



## Engineering Report 131

Issue 2 2012

Analysis package for assessing generation  
security capability – Users' guide

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### **Amendments since publication**

<b>Issue</b>	<b>Date</b>	<b>Amendment</b>
Issue 2	December, 2012	<p>Cosmetic revision of Issue 1 to align with the new ENA Engineering Report (EREP) template and Engineering Recommendation G0 Issue 1 2012 <i>Rules for structure, drafting and presentation of ENA engineering documents</i>.</p> <p>This issue does <u>not</u> include any principal technical changes.</p> <p>Details of all other technical, general and editorial amendments are included in the associated Document Amendment Summary for this Issue (available on request from the Operations Directorate of ENA).</p>

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## Foreword

This Engineering Report (EREP) is published by the Energy Networks Association (ENA) and comes into effect from the date of publication. It has been prepared under the authority of the ENA Engineering Policy and Standards Manager and has been approved for publication by the ENA Electricity Networks and Futures Group (ENFG). The approved abbreviated title of this engineering document is “EREP 131”, which replaces the previously used abbreviation “ETR 131”.

This engineering document is classed as a “qualifying standard” being listed in Appendix 2 of the Distribution Code (DCode). The revision of this engineering document has been modified in accordance with Standard Procedure 1 – Governance of Qualifying Standards as detailed in the *Constitution and Rules of the Distribution Code Review Panel*.

This issue supersedes ENA Engineering Report 131 Issue 1 2006, which is withdrawn.



## Introduction

This Engineering Report (EREP) describes how to use the computer spreadsheet, which was developed as part of the FES funded project for updating Engineering Recommendation P2/5. Initially, this computer spreadsheet was required in order to analyse many DG scenarios and to perform the wide range of sensitivity studies required for that work. The output of these studies provided the required input into the development of ER P2/6 [N1]. However it was anticipated that there could be a need to perform special studies in the future either to confirm previously tabulated values or to consider specific DG scenarios that are outside the range of the tabulated results in ER P2/6 [N1]. Such special studies are referred to in ETR 130 [N2] as Approach 3. They were permissible under ER P2/5 although P2/5 did not provide the detailed approaches or models for undertaking them.

The spreadsheet described in this EREP is only of a simple form, and has not been given either the presentation or user support that would be expected with commercial grade software. It is not commercially supported by the University of Manchester (formerly UMIST) or by the ENA. It is structured as a simple spreadsheet, automated by Visual Basic code which an engineer with a reasonable knowledge of the approach can use.

The spreadsheet calculates the contribution to System Security from DG connected to a particular network. The calculation of the contribution to System Security by DG continuously operating is explained in Clause 6 and that by DG not operating continuously in Clause 9. Clause 10 contains examples.

The capacity contribution calculation summates the outputs from multiple DG units and/or plants before calculating expected energy not supplied (EENS). This is different, and more accurate, than Approaches 1 and 2 described in ETR 130 [N2] where the respective contributions are summated after the individual EENS are derived. Where Wind Farms are part of this generation mix, 5-minute data must be used for accurate results. Alternatively 30 minute data can be used, provided correction factors are used (see 10.2.2 and 10.3.1).

## 1 Scope

The purpose of this Engineering Report is to support Engineering Recommendation P2/6 [N1] and Engineering Technical Report 130 [N2] by providing guidance on the use of a software package (hereafter referred to as the “spreadsheet”) developed for assessing the security capability of Distributed Generation (DG). The spreadsheet was developed by UMIST (now the University of Manchester) under contract to Future Energy Solutions (FES) as part of the development work for ER P2/6 [N1].

This Engineering Report provides guidance on how to use the spreadsheet developed by UMIST [N3] to assess the contribution to System Security from Distributed Generation (DG) assets as required under Approach 3 in ETR 130 [N2].

## 2 Normative references

The following referenced documents, in whole or part, are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

## **Other publications**

[N1] Engineering Recommendation P2/6, *System Security 2006*

[N2] Engineering Technical Report 130, *Application Guide for Assessing the Capacity of Networks Containing Distributed Generation*

[N3] Generation Security Capability Version 1.0 dated 06-06-19. Assessment programme developed by UMIST under contract to FES and available free of charge from ENA, see [www.energynetworks.org](http://www.energynetworks.org)

[N4] Developing the P2/6 Methodology, April 2004. Final report by UMIST for FES. Project DG/CG/00023/00/00

## **3 Terms and definitions**

For the purposes of this document, the following terms and definitions apply.

NOTE: Defined terms are capitalised where they are used in the main text of this report.

### **3.1**

#### **Declared Net Capability (DNC)**

declared gross capability of a DG plant, measured in MW, less the normal total parasitic power consumption attributable to that plant

NOTE 1: Declared Net Capability (DNC) as used in this Engineering Report should not be confused with declared net capacity (DNC) as used in the Electricity Act and Statutory Instrument 2001 3270.

NOTE 2: For the purpose of this definition the term "parasitic power consumption" refers to the electrical demand of the auxiliary equipment, which is an integral part of the DG, essential to the DG's operation. For the avoidance of doubt "parasitic power consumption" does not include demand supplied by the DG to an on-site customer.

NOTE 3: The DNC of Intermittent Generation is taken as the aggregate nameplate capacity of all the units within the DG plant, less any parasitic load.

### **3.2**

#### **Distributed Generation (DG)**

generating plant connected to the distribution network, where a generating plant is an installation comprising one or more generating units

### **3.3**

#### **First Circuit Outage (FCO)**

a fault or an arranged Circuit outage

NOTE: For classes of supply C to F in ER P2/6 [N1] supplies to consumers should not be interrupted by arranged outages.

### **3.4**

#### **Generator**

a person who generates electricity under licence or exemption from Section 4.1(a) of the Electricity Act 1989 or the Electricity (Northern Ireland) Order 1992



### **3.5**

#### **Intermittent Generation**

generation plant where the energy source of the prime mover can not be made available on demand

### **3.6**

#### **Non-intermittent Generation**

generation plant where the energy source of the prime mover can be made available on demand

### **3.7**

#### **Persistence ( $T_m$ )**

the minimum time for which output from Intermittent Generation must be continuously available if it can be considered to contribute to securing the Group Demand

### **3.8**

#### **Second Circuit Outage (SCO)**

a fault following an arranged Circuit outage

NOTE: The recommended levels of security are not intended at all times to cater for a first fault outage followed by a second fault outage or for a simultaneous double fault outage. Nevertheless, in many instances, depending upon switching and/or loading/generating arrangements, they will do so.

### **3.9**

#### **System Security**

the ability of a system to maintain supply to a defined level of demand under defined outage conditions

## **4 Spreadsheet structure**

### **4.1 General**

There are five key worksheets embedded within the spreadsheet. Many have dual functionality - results display and data entry. A sixth deals separately with Distributed Generation, which has an operational period of less than 24 h.

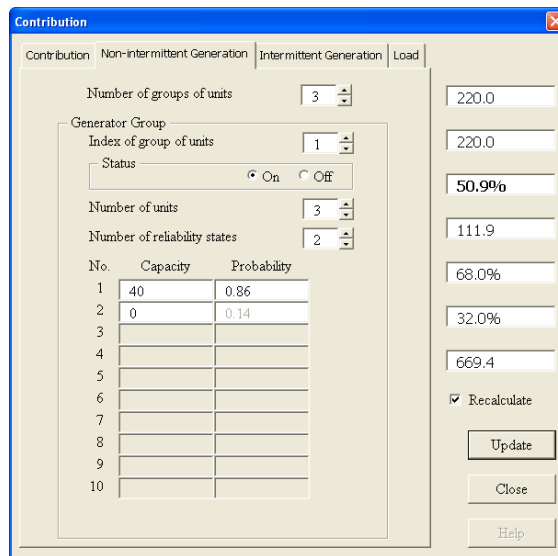
The input data (load and generation) is entered into the spreadsheet via the respective dialog box selected by the 'Edit Data' button. Calculated results (Contribution, Expected Energy Not Supplied, etc) are displayed in the Contribution dialog box.

### **4.2 Requirements**

In order to run the spreadsheet, Microsoft Excel 2000 ® or later version is required. Copy the supplied .xls file to the desired folder. It is necessary to enter any data tables, e.g. Intermittent Generation data, within the same folder. The Spreadsheet Macro security level (via the Tools menu) should be set to medium or less.

### 4.3 Data entry

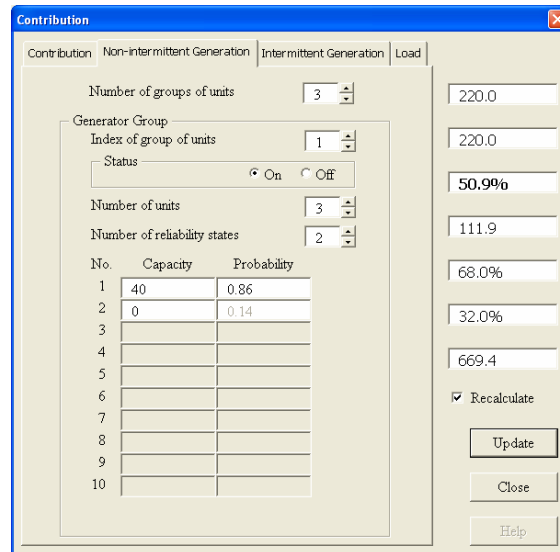
The dialog boxes shown in Figures 1 - 4 are obtained by pressing the 'Edit Data' button found on the 'Contribution', 'Generators', and 'Load' worksheets. The relevant tab within the dialog box is automatically selected according to which worksheet is open. If the check box next to the 'Recalculate' button is selected<sup>1)</sup>, recalculation will occur automatically when the 'Update' button is pressed. An information dialog box (see Figure 10) will then appear for the User to check that the Generation system is that expected before proceeding. All data input through the pages of the dialog box are then recalculated and saved in the appropriate worksheets. Data is entered using standard MS Windows ® procedures. Pressing the keyboard 'Return' key (↵) is the same as pressing the 'Update' button.



**Figure 1 — The dialog box of 'Contribution' page**

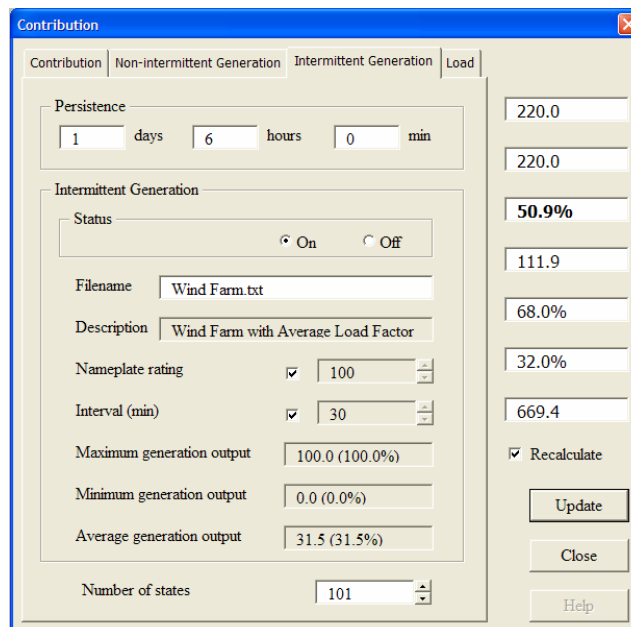
Figure 2 shows the dialog with the 'Non-intermittent Generation' tab selected. The input cells are the same as in the 'Non-Intermittent Generation' worksheet (see 6.1.1). A change in the Index field of a generator group automatically updates the worksheet data for this group. The final field of the 'Probability' column is automatically calculated. If the value becomes negative an error message will appear.

<sup>1)</sup> This is the default setting.



**Figure 2 — The dialog box of ‘Non-intermittent Generation’ page**

Figure 3 shows the dialog with the ‘Intermittent Generation’ tab selected. The input cells are the same as in the ‘Intermittent Generation’ worksheet (see 6.1.2). The ‘Description’, ‘Maximum’, ‘Minimum’ and ‘Average generation outputs are shown. If the ‘Nameplate rating’ and Interval (min)’ check boxes associated are unchecked, the values for these parameters can be changed.



**Figure 3 — The dialog box of ‘Intermittent Generation’ page**

Figure 4 shows the dialog box with the ‘Load’ duration profile tab selected. The data input cells are the same as in the ‘Load’ worksheet (see 7.1). Data can be entered here for the Load Duration Curve (LDC) or within the ‘Load’ worksheet, where the resulting load curve is displayed. This is the LDC used to determine the Distributed Generation contributions presented in Table 2 of P2/6 [N1].

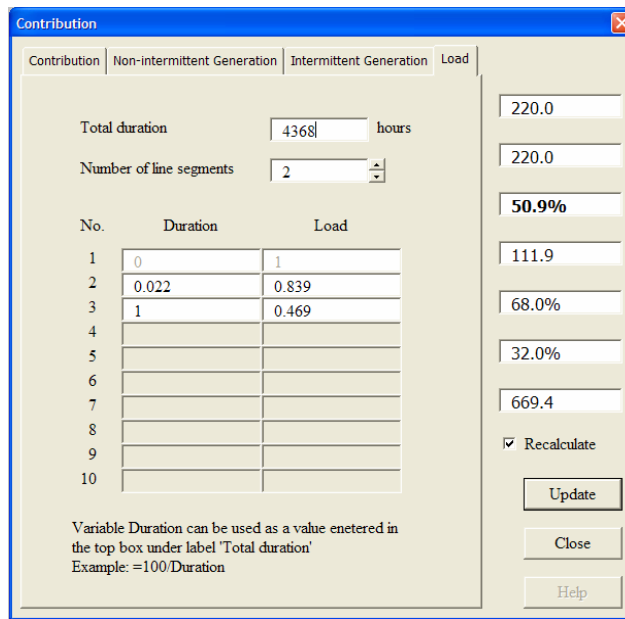


Figure 4 — The dialog box of the 'Load' page

## 5 Contribution worksheet

The main output values are saved and displayed in the 'Contribution' worksheet.

The evaluated results are shown in Figure 5. In order to ensure consistency of results with the chosen input data it is strongly recommended that the 'Recalculate' button is pressed.

The 'Installed capacity' field represents the total installed DG capacity connected within the network under study.

The 'Peak demand' field represents the peak value of the normalized load duration curve. This field is set within the spreadsheet to be total installed DG capacity. The value does not relate to the network demand and need not be considered when applying the methodology.

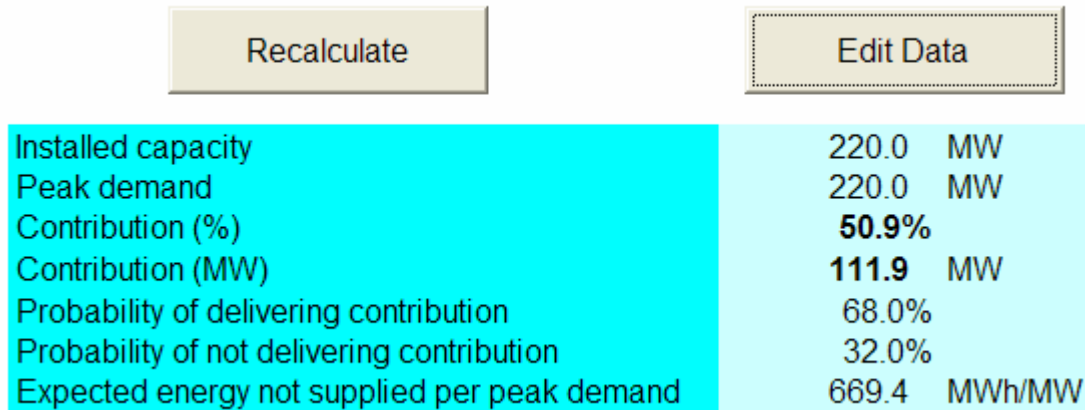
The 'Contribution' field shown in **BOLD** is the evaluated contribution to system security (F) from the generation, expressed as a percentage of the total installed capacity and in MW.

The 'Probability of delivering contribution' field represents the cumulative probability of those states in the Capacity Outage Probability Table (COPT) that are capable of supplying the evaluated contribution.

The counterpart field, 'Probability of not delivering contribution', is the complementary value.

The last field represents the expected energy not supplied per installed capacity.

The COPT of the system is shown in the 'Intermediate Results' worksheet and is not explained here<sup>2</sup>. It should be noted that the maximum number of states in this table must not exceed 65 000 (Spreadsheet limit), which is unlikely to limit the number of generation units.



**Figure 5 — Output**

## 6 Generation worksheet

### 6.1 Security contribution by generation that is capable of 24 h operation

#### 6.1.1 Non-intermittent Generation

Figure 6 shows part of the worksheet that contains the required data for Non-intermittent Generation. The DG is classified into groups of identical units. Three groups exist in this example. Each group has the following data:

- a) group number index;
- b) status of the group, where if the DG group is taken into account it is On, otherwise it is Off;
- c) number of DG in the group;
- d) number of states permitted in the capacity outage probability table, maximum 10;
- e) the capacity outage probability table of each unit in the group (the capacity outage probability table of the complete group and of the system is evaluated by the spreadsheet).

<sup>2</sup> See R. Allan, G. Strbac, P. Djapic, K. Jarrett, "Developing the P2/6 Methodology", FES ProjectDG/CG/00023/00/00, UMIST, April 2004.

Non-intermittent Generation		Edit Data					
Number of Groups of Units		3					
Index of Group of Units		1		2		3	
Status On / Off		On		Off		Off	
Number of Units		3		2		1	
Number of States		2		3		8	
	State No	Capacity (MW)	Probability	Capacity (MW)	Probability	Capacity (MW)	Probability
	1	40	0.86	60	0.8	100	0.8
	2	0	0.14	30	0.15	90	0.04
	3			0	0.05	80	0.02
	4					70	0.02
	5					60	0.02
	6					30	0.02
	7					15	0.02
	8					0	0.06
	9						
	10						

Figure 6 — Input data for Non-intermittent Generation

### 6.1.2 Intermittent Generation

Figure 7 shows part of the worksheet that contains the data for Intermittent Generation. This represents all the Intermittent Generation connected to a specific demand group. Persistence ( $T_m$ ) should be entered in the three yellow fields ('days', 'hours' and 'minutes'). In addition, values can be entered as a real number, i.e. value of 1.5 in field hours means 1 hour and 30 minutes. The Persistence  $T_m$  (days, hours, or minutes) is shown as output values in the lower right hand box. If the value of 'Status On / Off' field is "On", then the Intermittent Generation is taken into account when the contribution is calculated, otherwise not.

Intermittent Generation		Edit Data		
Persistence $T_m$ (days, hours, minutes)		1 days	6 hours	0 minutes
Status On / Off		On		
Filename		Wind Farm.txt		
Nameplate Rating (MW)		0	Value is given by file	
Interval (min)		0	Value is given by file	
Number of States		101		
			Persistence $T_m$ 1.25 days 30 hours 1800 minutes	

Figure 7 — Input data for Intermittent Generation

The 'Filename' field represents the name of the text file in which the chronological output DG profile is stored in the form of a column of thousands of values under the heading '[Data]'. An example is shown in Figure 8 and is taken from the sample text file (Wind Farm.txt<sup>3)</sup>). The 'Nameplate Rating (MW)' field represents the total DNC of the Intermittent Generation connected to the demand group. The 'Interval (min)' field represents the time interval between two consecutive values. If these two fields are set to zero, the program uses the corresponding values supplied in the [Header] part of the file. Finally, the 'Number of States' field represents the number of states to be formed in the capacity outage probability table. A value of "101" was used for the case studies in Sections 4 and 5 of the "Developing the P2/6 Methodology" report [N4] and is the recommended value to ensure that the result has an accuracy of better than 1%. Note that the [Header] structure must be reproduced exactly as displayed below to avoid the reporting a data entry error.

<sup>3)</sup> 'Wind Farm.txt' is an approximation to the averaged data used in P2/6. After applying the scaling factor (See 11.2.2) results are obtained which are close to those in Table 2-2A of P2/6.

NOTE: If the text file is open in another package, the spreadsheet may not be able to open it and hence the spreadsheet will not work correctly.

```
[Header]
File Version = 2.0
Data Description = Wind Farm with Average Load Factor
Nameplate Rating = 100
MW Data Interval = 30
minute

[Data]
99.36
98.51
99.57
99.15
99.26
99.26
96.28
.....
```

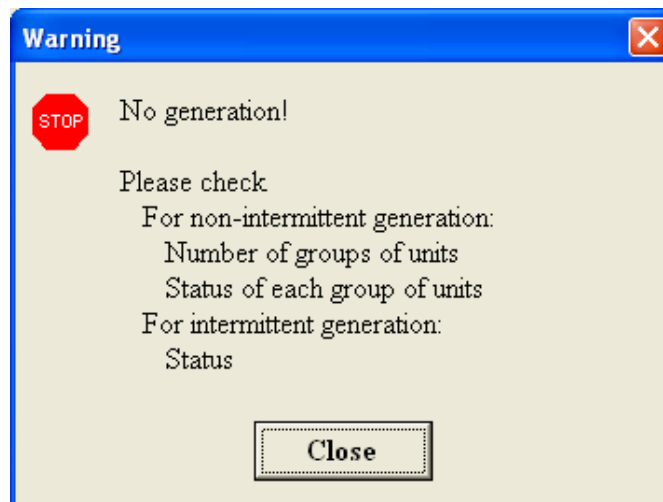
**Figure 8 — Example of file containing Intermittent Generation profile**

### 6.1.3 Data checks

Should an input error occur the information box similar to Figure 9 would display. The following wrong data or conditions will be detected.

- a) No Generation (as shown below).
- b) Profile file (i.e. no file, wrong header, empty row(s) in data section).
- c) Errors in the load duration curve.
- d) Data entry, or selection, errors.

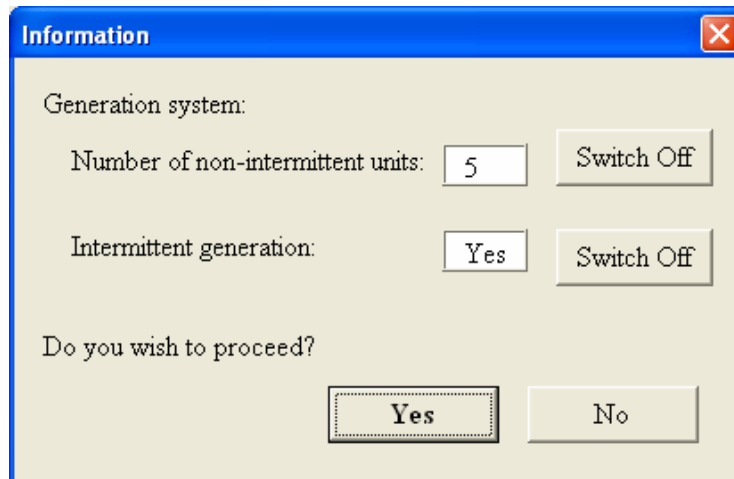
A help message will display within the box associated with the detected error.



**Figure 9 — The error information box**

#### 6.1.4 Selecting the generation mix

Before updating and recalculating the contribution from a mix of DG types it is important to check that the mix of DG is correct. Figure 10 clearly displays the number of Non-intermittent Generation units and whether Intermittent Generation is part of the DG system under study. It is then possible to switch off one part of the DG mix before proceeding.



The screenshot shows a dialog box titled 'Information' with a close button (X) in the top right corner. The dialog contains the following elements:

- Generation system:**
  - Number of non-intermittent units:** A text input field containing the number '5', followed by a 'Switch Off' button.
  - Intermittent generation:** A text input field containing the word 'Yes', followed by a 'Switch Off' button.
- Do you wish to proceed?:** Two buttons, 'Yes' and 'No', positioned at the bottom of the dialog.

Figure 10 — The mix of DG for which the DG contribution will be derived

## 7 Load worksheet

Figure 11 shows part of the 'Load' worksheet, which contains a piecewise linear representation of the load duration curve.

The 'Peak Value (MW)' field is set within the spreadsheet to be the total installed DG capacity, and is equal to the 'Peak demand' field referred to in Figure 5.

The 'Duration (h)' field is the total duration of the period of interest. The value of 4368 here represents a winter period of 4368 h, or six months duration. Ideally the time series demand data used to create this LDC should match the time series DG data and both should match the time of year for the respective FCO or SCO analysis. This is the LDC used to determine the Distributed Generation contributions presented in Table 2 of P2/6 [N1].

The 'Number of Lines' field represents the number of linear segments used to approximate the load duration curve. The maximum number of segments is nine. The normalised load duration profile is determined by this set of values. The first point of the load profile is always (0, 100%) and should not be changed. The subsequent points are user-defined variables and should be set to ensure a best-fit to the actual load duration curve (this assumes that the User has previously determined this). The illustrated graph is deduced by the spreadsheet.



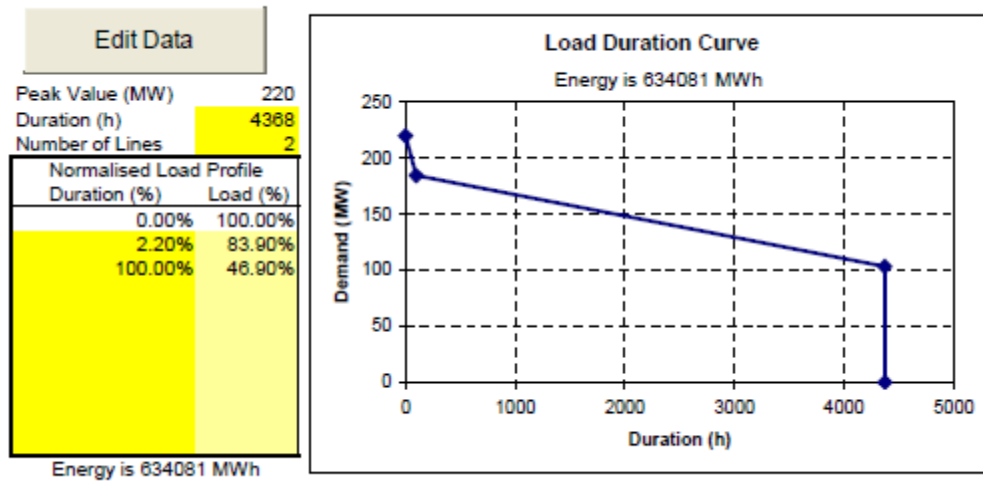


Figure 11 — Input data for load duration curve

## 8 Intermediate results spreadsheet

The DG capacity outage probability table is formed during the calculation and saved in the 'Intermediate Results' worksheet. No direct user input is required, and the user must not change any data so produced.

## 9 Shift Generation worksheet

### Contribution by generation operating for less than 24 hours per day

In order to reduce complexity, calculation of maximum additional contribution by the DG not continuously operated for a 24 h period is done completely in the 'Shift Generation' worksheet shown in Figure 12. The half-hourly typical load profile for a peak day representing the day of Group Demand is entered in the 'Demand (MW)' column. The calculation can be done for two operating periods, e.g. 8 h and 12 h, simultaneously. The start time and duration are entered for each case in the 'Time of Operation' part of the worksheet respectively. If the value of 'Start' time is "Auto", the operational time is calculated automatically and infers the same demand at the beginning and the ending time of operation. The result of the calculation, obtained by pressing the 'Refresh' button, is displayed in bold in the 'Maximum Additional Contribution' part of the worksheet. The 'Maximum contribution' is given as a percentage of two different values. The first value is the percentage of the peak demand, and the second value is the percentage of the firm capacity; the latter being obtained by calculating the contribution from the network and the continuously available DG.

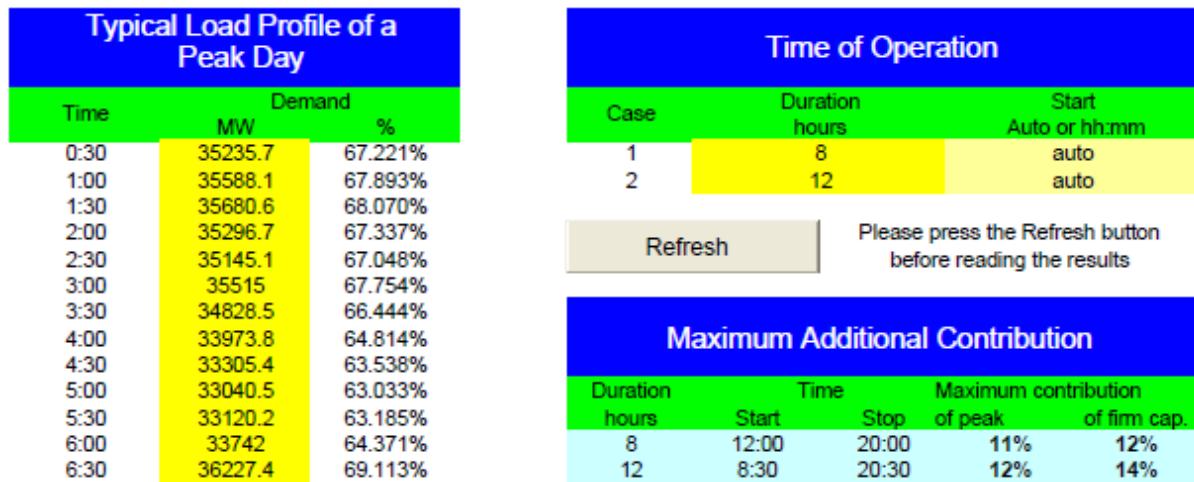


Figure 12 — Part of 'Shift Generation' worksheet

## 10 Examples

The User is to open Excel file 'Generation Security Capability' [N3] and then enable macros if asked to.

The ability to run macros should be tested by starting from menu Tools→Macro→Security. If the security level is high, the macros supplied in this file will not work. To enable the macros to be accepted the medium security level must be chosen. The security level should be returned to the preferred settings after finishing work on the file.

### 10.1 Non-intermittent Generation

#### 10.1.1 Example 1

Suppose that only Non-intermittent Generation is connected to the demand group. There are two identical DG units with the following parameters:

- a) rating capacity of each DG unit is 10 MW; and
- b) availability is 0.98.

#### Method

Activate 'Generation' worksheet and press 'Edit Data' button next to the title 'Non-intermittent Generation'. It will activate the dialog box shown in Figure 13. Enter "1" in the 'Number of groups of units' field. Also enter "1" in the 'Index of group of units' field. Set the Status to 'On'. In the 'Number of units' field enter "2", and also in the 'Number of reliability states' field. In the 'Capacity' column enter numbers "10" and "0" respectively, and in the 'Probability' column enter number "0.98". It should look as shown in Figure 13a). Choose 'Intermittent Generation' page and set the 'Status' to 'Off'. The other fields become irrelevant. Now press the 'Update' button. After checking that the generation system is correct, proceed. The contribution is 78.6% for the load duration curve shown in Figure 11.

**Figure 13a: Non-intermittent Generation Settings**

Number of groups of units: 1

Generator Group: 1

Index of group of units: 1

Status:  On  Off

Number of units: 2

Number of reliability states: 2

No.	Capacity	Probability
1	10	0.98
2	0	0.02
3		
4		
5		
6		
7		
8		
9		
10		

**Figure 13b: Intermittent Generation Settings**

Persistence: 1 days, 6 hours, 0 min

Intermittent Generation Status:  On  Off

Filename: Wind Farm.txt

Description: Wind Farm with Average Load Factor

Nameplate rating:  100

Interval (min):  30

Maximum generation output: [ ]

Minimum generation output: [ ]

Average generation output: [ ]

Number of states: 101

a)

b)

**Figure 13 — Settings for Example 1**

### 10.1.2 Example 2

Suppose that an additional DG unit is connected to the demand group with the following states 10, 5 and 0 MW and probability of states 0.8, 0.15 and 0.05, respectively.

#### Method

In the 'Number of groups of units' field enter the value "2". In the 'Index of group of units' field enter the value "2". Enter / check that the number of generators, along with the number of reliability states (1 and 3) is as Figure 14. Enter the revised capacity and check the probability data as shown in Figure 14. After ensuring that the first pair of generators is on, update and confirm that the contribution from 3 non-intermittent generators<sup>4)</sup> will be calculated. The resulting contribution is 67.9%.

<sup>4)</sup> If the recalculate box is ticked – Update will suffice.

The 'Contribution' dialog box has four tabs: 'Contribution', 'Non-intermittent Generation', 'Intermittent Generation', and 'Load'. The 'Intermittent Generation' tab is active. It contains the following settings:

- Number of groups of units: 2
- Generator Group Index of group of units: 2
- Status:  On  Off
- Number of units: 1
- Number of reliability states: 3

No.	Capacity	Probability
1	30	0.8
2	5	0.15
3	0	0.05
4		
5		
6		
7		
8		
9		
10		

On the right side of the dialog, there are several input fields and a 'Recalculate' checkbox:

- 50.0
- 50.0
- 67.9%
- 34.0
- 80.0%
- 20.0%
- 170.0
- Recalculate

Buttons at the bottom include 'Update', 'Close', and 'Help'.

Figure 14 — Additional settings for Example 2

The 'Information' dialog box displays the following information:

- Generation system:
- Number of non-intermittent units: 3
- Intermittent generation: No
- Do you wish to proceed?

Buttons at the bottom are 'Yes' and 'No'.

Figure 15 — Information check box

## 10.2 Intermittent Generation

### 10.2.1 Example 3

Suppose that only Intermittent Generation supplies the demand. The total installed capacity is 100 MW, and average half hourly power output for a year is supplied in the file 'Wind Farm.txt'. The contribution is calculated for a persistence of 3 h.

#### Method

Select the 'Non-intermittent Generation' page and in the 'Number of generators group' enter "0". This will blank out the data area. Then ensure that the text file 'Wind Farm.txt' is saved in the same folder as this Spreadsheet. In the 'Intermittent Generation' page set the 'Status' to 'On'. Now enter data as shown in Figure 16. Press the 'Update' button, and confirm that the Generation System is correct, and proceed. The contribution is 25.7%.

**Figure 16 — Settings for Example 3**

**Figure 17 — Information check box**

**10.2.2 Data scaling**

In the last example, the data used (Wind Farm.txt) has data samples averaged over 30 minutes. In the “Developing the P2/6 Methodology” report [N4] Sensitivity studies were carried out with data capture intervals down to one minute in order to understand how short term fluctuations in wind output would affect the contribution for different values of  $T_m$ . From this work, the recommended sample rate to take account of this was deemed to be five minutes. As five minute data is not generally available, a table of ‘Correction Factors’ for wind farm contribution, for typical values of  $T_m$ , was created. This can be applied to the result(s) of this calculation. This Table is reproduced below as Figure 18.

Wind profile resolution	Correction factors in % for $T_m$ (h) of:					
	½	2	3	18	24	120
5 min	97	93	92	85	84	42
1 min	93	88	87	75	72	31

**Figure 18 — Correction factors from 30 min data for a single wind farm**

These correction factors only apply to wind data. Note that the correction increases with  $T_m$ .

After applying the 5 min correction factor above for a 3h value of  $T_m$ , the contribution from this wind farm is 23.6% ( $P2/6 = 24\%$ ).

### **10.3 Combining Intermittent Generation and Non-intermittent Generation**

#### **10.3.1 Example 4**

Suppose that the demand is supplied with all DG from the previous examples.

#### **Method**

In the 'Non-intermittent Generation' page return the 'Number of groups of units' back to "2". The resultant contribution is now 44.9%.

NOTE: By not using 5-minute data for Wind, this result will contain a small residual error (Actual contribution for wind is 92% of calculated value at  $T_m$  set at 3 h). If the contribution is required beyond, 24 h, then the calculation of contribution for Intermittent Generation and Non-intermittent Generation should be carried out separately. The scaling factor applied to the intermittent result, and the two results summated.

