REACTIVE POWER MARKET

BM UNITS PROVIDING OBLIGATORY REACTIVE POWER SERVICES

METHODOLOGY FOR CALCULATION OF REACTIVE POWER CAPABILITY DATA

Issue 18

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IMPORTANT - THIS DOCUMENT SUPERSEDES ISSUE 17

This document has been published by National Energy System Operator Limited ("The Company").

The Company has, in good faith, made, devised and compiled the assumptions, methodologies, calculations and other information contained in this document for the purposes of the Tender process described in its Invitation to Tender, relating to Reactive Power services. However, neither The Company nor their employees and advisers accept any liability whatsoever for any loss or damage caused directly or indirectly by any omission or error or misstatement contained herein. Accordingly, recipients of this document should satisfy themselves as to the appropriateness of such assumptions and the accuracy and completeness of such methodologies, calculations and other information and, in particular, their suitability for use in connection with the Invitation to Tender.

This document forms part of the Invitation to Tender documentation and should be read in conjunction with the other documents. In particular, you are referred to the document entitled "Invitation to Tender and Guidance Notes for the Completion of Tenders".

Please Note:

Certain sub-Sections in this document refer to figures (data) as set out in the relevant Mandatory Services Agreement. In the case of a new provider (Generator) of Reactive Power services where the relevant Mandatory Services Agreement has not yet been entered into, but where the relevant schedules to the Mandatory Services Agreement have been agreed by the Generator and The Company prior to the submission of the Tender, reference to the relevant Mandatory Services Agreement shall be deemed to be reference to the relevant Mandatory Services Agreement to be entered into.

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1. BACKGROUND DATA AND ASSUMPTIONS

1.1 The most recent Generator Performance Chart submitted in accordance with Grid Code OC2.4.2, together with other data from Schedule 1 of the Grid Code DRC, is taken as the basis for the following procedure.

1.2 It is assumed that:

- the generator stator terminal voltage is nominal; and
- the AVR is in service, in voltage following mode; and
- no account is taken of HV system voltage or step-up transformer rating or tap limitations in reading the Generator Performance Chart.

1.3 The following values for MW outputs are used:

- the value for Rated MW is that specified within Schedule 1 of Grid Code DRC;
- the value for Full Output has been derived by summing the Registered Capacity and the auxiliary load (MW) specified in Grid Code DRC Schedule 1;
- the value for Minimum Output has been derived by summing the Minimum Generation and the auxiliary load (MW) given in Grid Code DRC Schedule 1;
- note that both Full Output and Minimum Output are defined within Grid Code BC2.A.3.1;
- note that Registered Capacity is defined within the Glossary & Definition section of the Grid Code.

1.4 The values for Full Output and Minimum Output should describe the normal operating (MW) range of a BM Unit. If the values quoted do not adequately address this purpose, this should be indicated to The Company and appropriate values agreed.

1.5 Where the information in sub-Section 1.3 is unavailable for CCGT Units, the capability matrices have been left blank for the appropriate data to be agreed between The Company and a Generator.

1.6 All Reactive Power capability data is expressed as positive, whole numbers to the nearest Mvar.

1.7 All data at the LV is referenced to generator stator terminals for a BM Unit (or CCGT Module). Reactive Power capability data at the Commercial Boundary is derived for each BM Unit.

2. THE GENERATOR PERFORMANCE CHART AND POPULATING THE LV CAPABILITY MATRIX

Leading Reactive Power Capability Data

2.1 The Leading Reactive Power capability at Rated MW is determined by the requirements of CC.6.3.2, i.e. 0.95pf lead, or any derogation thereto (where it is still applicable). Where a derogation is applicable, the Power Factor specified in the derogation as the present capability replaces 0.95pf lead in sub-Sections 2.2 to 2.4 below.

2.2 The assumption used is that the Leading capability at Rated MW and below is defined by the machine stability limit, hereafter referred to as the Leading limit, see Figure 1.

2.3 If the Leading limit does not pass through the point corresponding to 0.95 pf lead at Rated MW, this line is extrapolated back to the zero-MW axis, see Figure 2. A modified leading limit is created by extrapolating from the point of intersection on the zero-MW axis through the point corresponding to 0.95 pf lead at Rated MW.

2.4 Once the Leading limit has been adjusted to pass through the point corresponding to 0.95 pf lead at Rated MW, then:

- the Reactive Power capability at Minimum Output is obtained by extrapolating the Leading limit (as modified) down to the Minimum Output MW level; and

- the Reactive Power capability at Full Output is obtained by taking the lesser (i.e. the smaller number of *Leading* Mvar) of the intersection of the Leading limit (as modified) with Full Output or the intersection of the stator MVA limit with Full Output, see Figure 3.

The Leading and Lagging Reactive Power capability values obtained for Minimum Output and Full Output levels respectively must be at the same ambient temperature consistent with the data submitted in accordance with Schedule 1 of the Grid Code DRC.

Lagging Reactive Power Capability Data

2.5 The Lagging Reactive Power capability at Rated MW is determined by the requirements of CC.6.3.2, i.e. 0.85pf lag, or any derogation thereto (where it is still applicable). Where a derogation is applicable, the Power Factor specified in the derogation as the present capability replaces 0.85pf lag in 2.6 to 2.9 below.

2.6 The assumption is that the Lagging capability at Rated MW and below is defined by the machine rotor current limit, hereafter referred to as the Lagging limit, see Figure 1.

2.7 If the rotor current limit depicted on the Generator Performance Chart does not extend to the Full or Minimum Output level, it will be extended either as an arc of a circle, centered at (0 MW, $-1/X_d$ Mvar), or otherwise as judged appropriate in the context.

2.8 If the rotor current limit does not pass through the point corresponding to 0.85 pf lag at Rated MW, then the difference in Mvars between the point of intersection of the rotor current limit and the Rated MW line, and the point corresponding to 0.85 pf lag at Rated MW is calculated. A Lagging limit, passing through 0.85 pf at Rated MW, is derived by subtracting (or adding, if appropriate) this Mvar difference from the rotor current limit, at any value of MW (i.e. the rotor current limit is effectively translated, bodily, to left or right), see Figure 2.

2.9 Once the Lagging limit has been adjusted to pass through the point corresponding to 0.85 pf lag at Rated MW, then:

- the Reactive Power capability at Minimum Output is obtained by extrapolating the Lagging limit (as modified) down to the Minimum Output level; and

- the Reactive Power capability at Full Output is obtained by taking the lesser (i.e. the smaller number of *Lagging* Mvar) of the intersection of the Lagging limit (as modified) with Full Output or the intersection of the stator MVA limit with Full Output, see Figure 3.

The Leading and Lagging Reactive Power capability values obtained for Minimum Output and Full Output levels respectively must be at the same ambient temperature consistent with the data submitted in accordance with Schedule 1 of the Grid Code DRC.

LV Capability Matrix

2.10 The Leading and Lagging Reactive Power capability at the generator stator terminals will be set out in Table B of Appendix 1, Section A, Part I in the relevant Mandatory Services Agreement.

2.11 The figures referred to in sub-Section 2.10 above are subject to agreement between The Company and a Generator, using the methodology set out here.

2.12 The values referred to in sub-Section 2.10 above constitute the Reactive Power capability of a Generating Unit at Full Output, at Rated MW and at Minimum Output at the generator stator terminals equivalent to the minimum Reactive Power capability required under and in accordance with the Connection Conditions of the Grid Code. It is necessary to agree these values (in writing in the form of the generic Reactive Power attachment included in Appendix C of the Invitation to Tender and Guidance Notes for the Completion of Tenders) with The Company prior to submitting a Tender for a Market Agreement.

3 DERIVATION OF THE REACTIVE POWER CAPABILITY AT RATED MW AT THE COMMERCIAL BOUNDARY FOR THE DEFAULT PAYMENT ARRANGEMENTS

3.1 The values of Leading and Lagging capability for Rated MW referred to in sub-Section 2.10 above are used to calculate the equivalent Leading and Lagging capability at Rated MW at the Commercial Boundary for each BM Unit by application of the relevant "LV-to-HV" formulae in Appendix 8 of Schedule 3 to the Connection and Use of System Code.

3.2 The current DRC data is used in the "LV-to-HV" calculations above.

3.3 There are separate "LV-to-HV" formulae for steam Generating Units and CCGT Modules.

3.4 The figures for Leading and Lagging capability at Rated MW and at the Commercial Boundary for each BM Unit are set out in Table A of Appendix 1, Section A, Part I in the relevant Mandatory Services Agreement.

3.5 The figures referred to in sub-Section 3.4 above and formulae referred to in sub-Section 3.3 above are subject to agreement between The Company and a Generator, using the methodology adopted by all Tenderers.

3.6 The figures referred to in sub-Section 3.4 above will constitute the Reactive Power capability of a BM Unit at Rated MW and at the Commercial Boundary equivalent to the minimum Reactive Power capability required under and in accordance with the Connection Conditions of the Grid Code. It is necessary to agree these values (in writing in the form of the generic Reactive Power attachment included in Appendix C of the Invitation to Tender and Guidance Notes for the Completion of Tenders) with The Company prior to submitting a Tender for a Market Agreement.

Modifications

3.7 It may be necessary for The Company and a Generator to agree modified "LV-to-HV" formulae where either the site or connection configuration requires or any restrictions apply, e.g. if there is an active MVA constraint imposed by the unit step-up transformer.

4. DERIVATION OF THE REACTIVE POWER CAPABILITY AT NOMINATED REGISTERED CAPACITY AT THE COMMERCIAL BOUNDARY FOR MARKET TENDERS

4.1 Unless otherwise expressly indicated by the Tenderer, all Reactive Power capability data specified on the tender sheets must be at the ambient temperature at which the Reactive Power capability is shown in the relevant Mandatory Services Agreement for the purpose of the default payment arrangements for the Obligatory Reactive Power Service.

4.2 The values of Leading and Lagging capability for Full Output referred to in sub-Section 2.10 above are used to calculate the equivalent Leading and Lagging capability at the Nominated Registered Capacity and at the Commercial Boundary for each BM Unit by application of the "LV-to-HV" formulae in Schedule B, Part II of the Specimen Market Agreement provided in the Tender Pack.

4.3 Unless otherwise agreed between The Company and a Generator, as set out in sub-Sections 4.11 to 4.13 below, the current Registered Capacity is used for Nominated Registered Capacity and the equivalent value for Full Output will be used.

4.4 Unless otherwise agreed between The Company and a Generator, as set out in sub-Sections 4.14 and 4.15 below, the current DRC data is used in the "LV-to-HV" calculations above.

4.5 There are separate "LV-to-HV" formulae for steam plant and Gas Turbine Units.

4.6 The figures for Leading and Lagging capability at Nominated Registered Capacity and at the Commercial Boundary for each BM Unit are set out in the Reactive Power Attachment (see section 4.3.4 of the Invitation to Tender and Guidance Notes for the Completion of Tenders).

4.7 The figures referred to in sub-Section 4.6 above and formulae referred to in sub-Section 4.2 above are subject to agreement between The Company and a Generator, using the methodology set out here.

4.8 The figures referred to in sub-Section 4.6 above will constitute the Reactive Power capability of a BM Unit at Nominated Registered Capacity and at the Commercial Boundary equivalent to the minimum Reactive Power capability required under and in accordance with the Connection Conditions of the Grid Code. It is necessary to agree these values (in writing in the form of the generic Reactive Power attachment included in Appendix C of the Invitation to Tender and Guidance Notes) with The Company prior to submitting a Tender for a Market Agreement.

4.9 The figures referred to in sub-Section 4.6 will constitute the second or (as the case may be) third Tendered Capability Breakpoints, in respect of both Leading and Lagging Mvars, which must be equivalent to the Reactive Power capability of the BM Unit which a User is obliged to provide under and in accordance with the Connection Conditions of the Grid Code.

4.10 Where a Tender is accepted for the Obligatory Reactive Power Service, both these figures and the formulae will be incorporated within the Market Agreement.

Nominated Registered Capacity

4.11 Where a Generator anticipates that the actual Registered Capacity for a BM Unit on the next Contract Start Day will not be based on the Full Output as set out in the relevant Mandatory Services Agreement, then a Generator can indicate this to The Company and an appropriate value for Nominated Registered Capacity be agreed. The equivalent value for Full Output will be agreed in accordance with Section 1 above.

4.12 The Company and the Generator will then be required to agree the appropriate values for the LV capability matrix for a value of Full Output equivalent to the Nominated Registered Capacity, in accordance with Section 2 above.

4.13 The Company and the Generator will then be required to agree the appropriate values for Leading and Lagging Reactive Power capability at the Nominated Registered Capacity at the Commercial Boundary in accordance with sub-Sections 4.1 to 4.10 above. These will be recorded in the Reactive Power Attachment.

DRC Data

4.14 Where a Generator anticipates that any of the DRC data required in the application of the “LV-to-HV” formulae referred to in sub-Section 4.2 above on the next Contract Start Day will be different from the current data, then a Generator can indicate this to The Company and the appropriate values for DRC data can be agreed.

4.15 The Company and the Generator will then be required to agree the appropriate values for Leading and Lagging Reactive Power capability at Nominated Registered Capacity at the Commercial Boundary in accordance with sub-Sections 4.1 to 4.10 above.

Modifications

4.16 It may be necessary for The Company and a Generator to agree modified “LV-to-HV” formulae where either the site or connection configuration requires or any restrictions apply, e.g. if there is an active MVA constraint imposed by the unit step-up transformer.

5. GUIDANCE FOR Mvar REDECLARATIONS

5.1 Introduction

For the avoidance of doubt, any reduction in the capability of a Generating Unit (irrespective of whether payments are made for the Obligatory Reactive Power Service via default payment arrangements or Market Agreement) shall be notified to The Company via a redeclaration of Mvar capability. This obligation to redeclare Mvar capability comes from BC2 of the Grid Code. The Mandatory Services Agreements mirror this obligation, but do not impose anything over and above that contained in the Grid Code. An example of a Mvar Redeclaration form is provided in BC2 of the Grid Code and is also shown in Appendix A.

As a Grid Code requirement all formal Mvar redeclarations are to be given on a unit basis at the generator stator terminals. **Leading and Lagging Reactive Power capabilities must be provided at Rated, Full and Minimum MW Outputs.**

5.2 Completing the "Redeclaration of Mvar Data" Form

Where the Generating Unit has both a Leading and Lagging Reactive Power capability, the redeclared capability should be expressed as a positive integer.

Where the Generating Unit does not have a Reactive Power capability (Leading or Lagging) then the minimum Reactive Power capability should be expressed as a negative integer or zero.

Example: redeclarations for a genset with capabilities of 100 Mvar lead and 200 Mvar lag are tabulated below:

Redeclaration	Lead	Lag
Reduced lead capability by 50 Mvar	50	200
No lead capability	0	200
No lead capability & lag capability from 10 Mvar only	-10	200
No lag capability & lead capability from 30 to 100 Mvar	100	-30

5.3 Redeclaration Requirements

As illustrated in the diagram overleaf, redeclaration of Mvar capability is required where, inter alia:-

1) The Generating Unit is operating outside its normal operational envelope of registered characteristics (i.e. operating above Full Output, or below the Minimum Output).

2) For any MW Loading within the operating range, the Generating Unit is technically incapable of providing the corresponding lead/lag output as interpolated from the performance chart (possible reasons for a redeclaration may range from temporary brushgear sparking or stuck taps on a generator transformer, through to, major rotor deficiencies).

For the avoidance of doubt redeclarations of Mvar capability are not required where, inter alia:-

3) The Generating Unit has a sustained period of MW unavailability, for example due to maintenance outage.

Plant changes that require amendments to the registered DRC data will be reflected by changes to the Mvar capability in the relevant Mandatory Services Agreement by an amending agreement. Any change to such parameters should be promptly notified to The Company in accordance with the Grid Code.

5.4 CCGT Modules

For CCGT Modules, Mvar redeclarations are made on a CCGT Unit basis, again at the generator stator terminals. This enables The Company to properly study the effect of the loss of capability on the National Electricity Transmission System. The format and procedure for redeclarations is exactly the same as for other Generating Units (example in Appendix A). Note that The Company will recalculate the overall capability of the CCGT Module using the methods described within this document for the purposes of HV despatch.

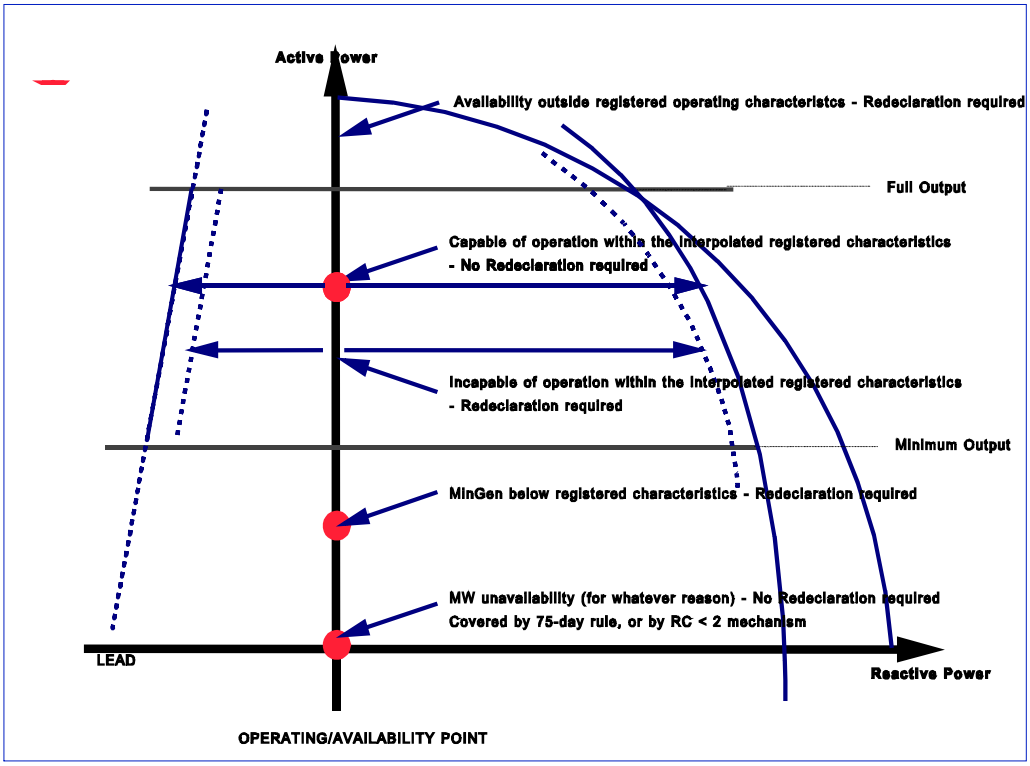

Active Power
Availability outside registered operating characteristcs - Redeclaration required
Full Output
Capable of operation within the interpolated registered characteristics
- No Redeclaration required
Incapable of operation within the interpolated registered characteristics
- Redeclaration required
Minimum Output
MinGen below registered characteristics - Redeclaration required
MW unavailability (for whatever reason) - No Redeclaration required
Covered by 75-day rule, or by RC < 2 mechanism
LEAD
Reactive Power
OPERATING/AVAILABILITY POINT

FIGURE 1

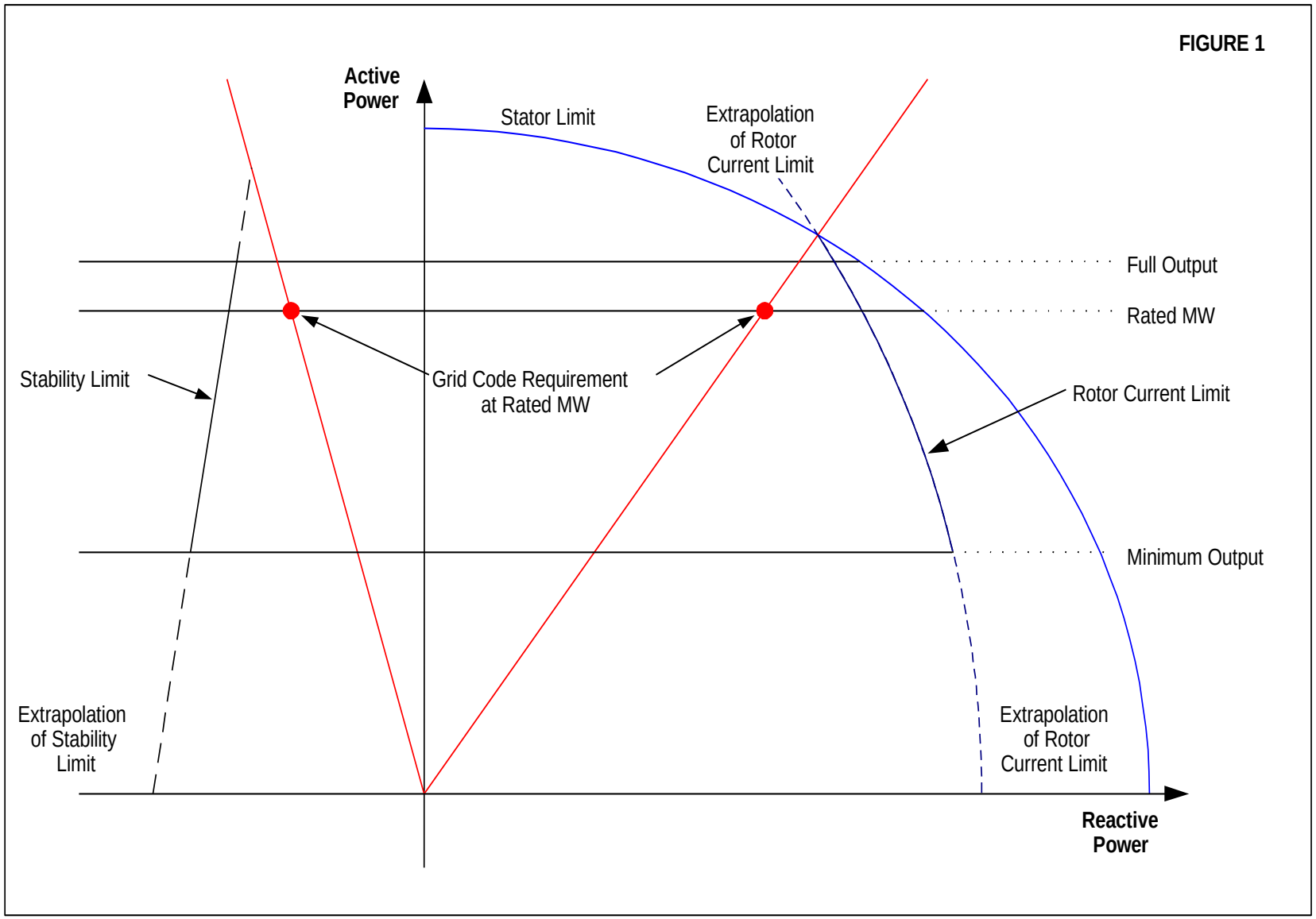
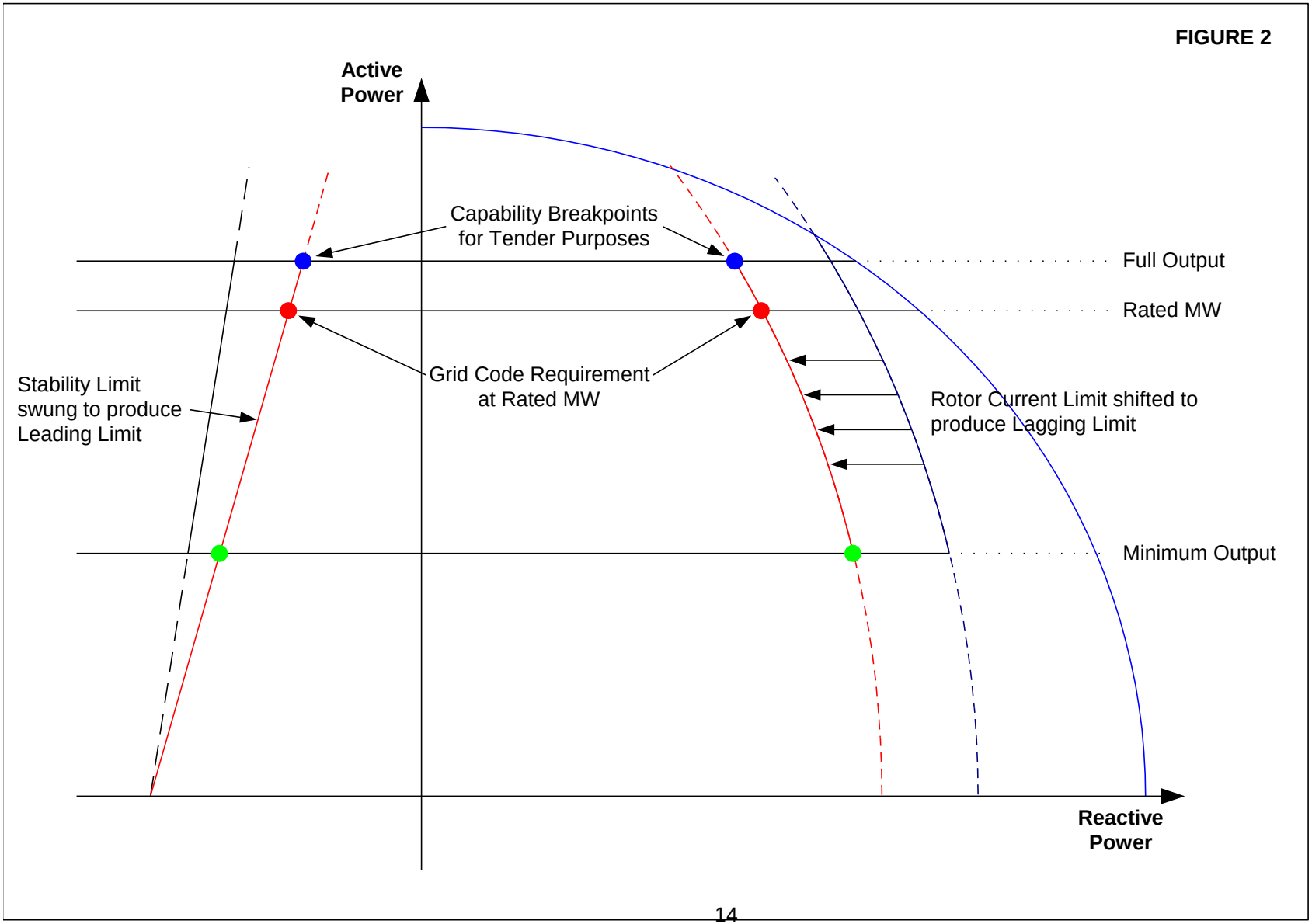

Active Power
Stator Limit
Extrapolation of Rotor Current Limit
Full Output
Rated MW
Stability Limit
Grid Code Requirement at Rated MW
Rotor Current Limit
Minimum Output
Extrapolation of Stability Limit
Extrapolation of Rotor Current Limit
Reactive Power

FIGURE 2


Active Power
Capability Breakpoints for Tender Purposes
Full Output
Rated MW
Grid Code Requirement at Rated MW
Stability Limit swung to produce Leading Limit
Rotor Current Limit shifted to produce Lagging Limit
Minimum Output
Reactive Power

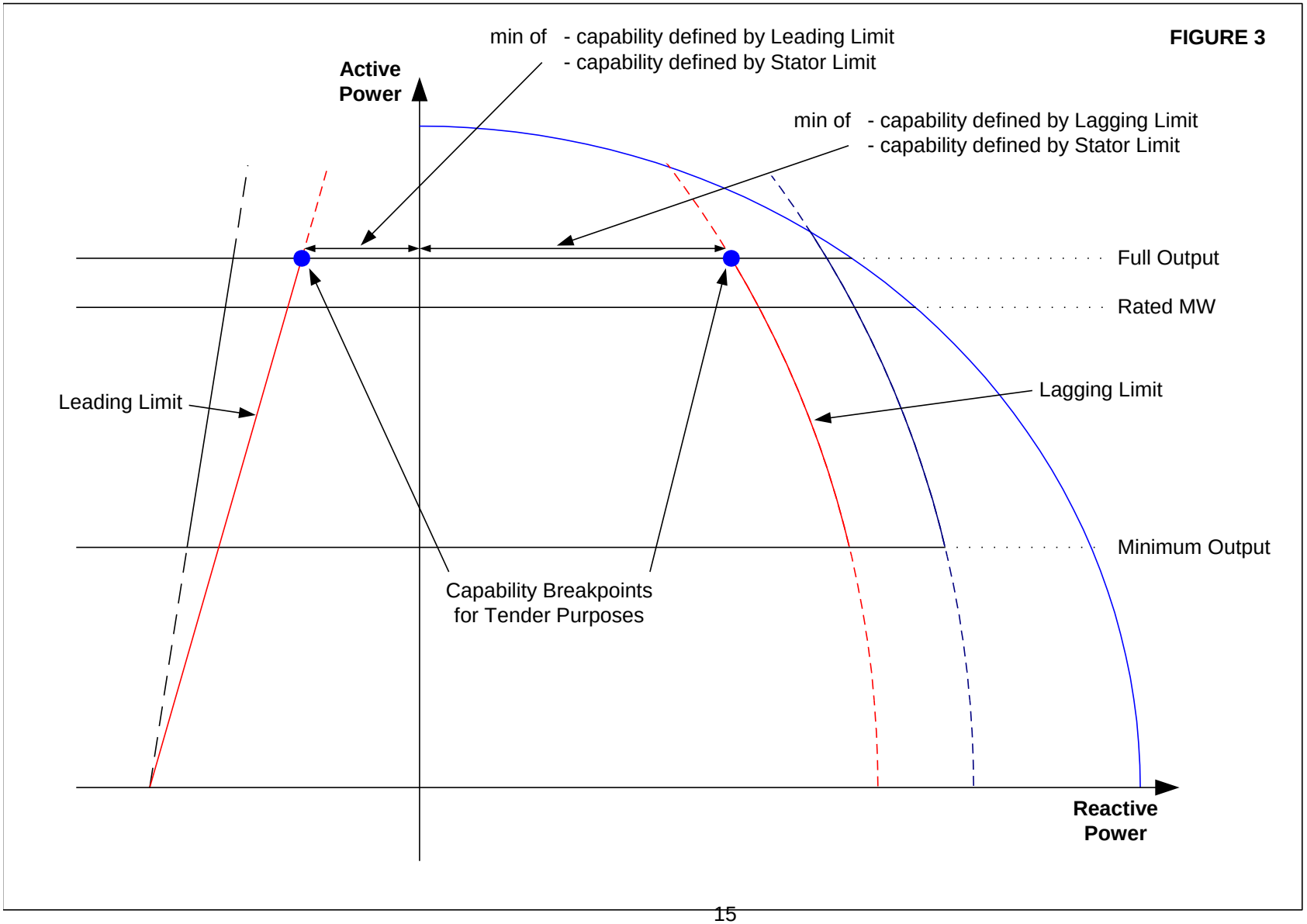

min of - capability defined by Leading Limit
- capability defined by Stator Limit
Active Power
min of - capability defined by Lagging Limit
- capability defined by Stator Limit
Full Output
Rated MW
Leading Limit
Lagging Limit
Minimum Output
Capability Breakpoints for Tender Purposes
Reactive Power

FIGURE 3

APPENDIX A

REDECLARATION OF Mvar DATA FORM

Optional Logo

To: Electricity National Control Centre
From : [*Company Name & Location*]

REDECLARATION OF Mvar DATA

NOTIFICATION DETAILS

NOTIFICATION TIME: HRS: MINS DD/MM/YY

(1) CONFIRMATION OF A TELEPHONE CONVERSATION..... .....Tick this box

Between _____ of NATIONAL ENERGY SYSTEM OPERATOR LIMITED AND _____ of [*Company Name*]
(2) FIRST NOTIFICATION OF A CHANGE .....Tick this box
(Complete either 1 or 2)

GENERATING UNIT	

Start Time/Date (if not effective immediately)

REACTIVE POWER CAPABILITY AT GENERATOR STATOR TERMINAL (at rated terminal volts)

	MW	LEAD (Mvar)	LAG (Mvar)
AT RATED MW			
AT FULL OUTPUT			
AT MINIMUM OUTPUT			

GENERATING UNIT STEP- UP TRANSFORMER DATA

TAP CHANGE RANGE (+%,-%)	TAP NUMBER RANGE

OPTIONAL INFORMATION (for NGET use only) **-**
REACTIVE POWER CAPABILITY AT COMMERCIAL BOUNDARY (at rated stator terminal and nominal system volts)

	LEAD (Mvar)	LAG (Mvar)
RATED		

Predicted End Time/Date (to be confirmed by redeclaration)

Redeclaration made by (Signature) _____