Single Electricity Market

Loss of Load Probability Curve for Capacity Payment Mechanism

Decisions Paper and Response to Detailed Comments

AIP-SEM-07-65

30th March 2007

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1. INTRODUCTION

On 13 February 2007 the Commission for Energy Regulation and the Northern Ireland Authority for Energy Regulation (the Regulatory Authorities) published a consultation paper entitled *"Loss of Load Probability Curve for Capacity Payment Mechanism"*[1]. This paper considered a number of issues key to the Loss of Load Probability Curve that will be used to distribute Capacity Payments across the course of each trading Month in the SEM Capacity Payment Mechanism. The paper discussed a number of options for the determination of the curve, in each case setting out the pros and cons and indicating the options which the Regulatory Authorities were minded to select. An addenda paper was published on 2 March 2007 to further assist respondents, which displayed a graphical example of how capacity payments could be distributed in 2007 under the methods proposed in the Consultation.

Comments were invited on the proposals contained in the consultation document by 13 March 2007. Responses were received from five organisations. This paper sets out the Regulatory Authorities' response to the comments received and presents the conclusions of the Regulatory Authorities in the matters addressed by the consultation.

The main body of this paper focuses on the key issues and presents the Regulatory Authorities' conclusions in relation to the determination of the Loss of Load Probability Curve, while more detailed responses to each of the comments received are provided in Appendix A.

[1] http://www.allislandproject.org/2007/AIP-SEM-07-10.pdf

2. BACKGROUND

On 15th July 2005 the Regulatory Authorities issued a paper titled "*Capacity Payment Mechanism and Reserve Charging High Level Decision paper*"[2] in which the Regulatory Authorities stipulated their intention to develop a fixed revenue capacity payment mechanism which would provide a degree of financial certainty to generators under the new market arrangements and a stable year-to-year pattern of capacity payments.

The principles outlined in the July 2005 paper were incorporated into the design of the CPM in the all-island Trading and Settlement Code (T&SC) and on 21st December 2005, the Regulatory Authorities published a draft version (version 0.10) of the proposed T&SC for the SEM, with comments invited by 20th January 2006. Subsequent to the publication of this document the Regulatory Authorities determined that a more detailed consideration of the comments received on the design of the CPM was required and on 3rd March 2006 the Regulatory Authorities issued a further consultation paper[3]. Following a further open forum discussion the Regulatory Authorities issued a Decision document in July 2006[4] in which they indicated the general support shown by respondents to the proposals for the determination of the Annual Capacity Payment Sum. On 13 February 2007 the Regulatory Authorities issued a detailed consultation into the proposed methodology for the determination of the Loss of Load Probability Curve[1] that will be used to distribute Capacity Payments across the course of each trading Month. This paper sets out the decisions of the Regulatory Authorities in relation to the issues raised in this latter consultation and provides responses to the detailed comments received in response to the consultation.

[2] http://www.allislandproject.org/2006/AIP-SEM-53-05.pdf
[3] http://www.allislandproject.org/2006/AIP-SEM-15-06.pdf
[4] http://www.allislandproject.org/2006/AIP-SEM-95-06.pdf

3. DECISIONS

- The calculation method will be the 'Stacking' method as described in Section 3.1.4 of the Consultation Document.

- The Stacking method will calculate LOLP as a function of Margin as proposed in the Consultation Document.

- The LOLP curve will be calculated for Margins defined at whole megawatt intervals, starting with 0MW and increasing to the total installed capacity in the system (0, 1, 2 … Total).

- The LOLP curve will be recalculated and published at least 20 days prior to the commencement of a new market Year. The curve will not be updated during the year, except upon the market entry or exit of a Generator Unit of Registered Capacity 50MW or more. In these circumstances, the curve is to be recalculated and published at least 5 working days prior to the entry or exit of the unit in question.

- A single LOLP curve will apply in all circumstances under both the Variable (ex-ante) and ex-post components of the Capacity Payment Mechanism.

- The LOLP curve will be calculated from the system state in which no market registered conventional plant is on scheduled outage. That is, the capacities of all market conventional plant will be included in the calculation of the static LOLP curve.

- Generator Capacities for each unit will be the same values as implemented in the determination of the Capacity Requirement for the Capacity Payment Mechanism, based on information received from participants under their Generation License conditions.

- Forced outage probabilities (FOPs) based on the most recent five years of historical data as applied in the determination of the Ex-ante Margin.

- The Generator Set used in compiling the generation stack in the Stacking methodology will include all conventional units that are eligible to receive Capacity Payments.

- The distribution of capacity payments in the Variable (ex-ante) and ex-post components across the course of each Month will be flattened using a Power Factor technique (described in Section 8) on the LOLP values ascribed to the systems look-up table. The Power Factor will be set to 0.35 for both components of the Payment Mechanism.

4. METHODOLOGY FOR THE CALCULATION OF THE LOLP CURVE

4.1. LOLP as a function of Margin

The Consultation Document proposes to define LOLP as a function of Margin, where Margin is defined as the difference between Capacity and Demand.

4.1.1. Responses

Three respondents voiced concern about the assumption that LOLP is going to be defined based only as a function of Margin instead of both Capacity and Demand.

One of the three respondents argued that there could be difference in LOLP for scenarios in which the make-up of the generation stack varied; such that the LOLP at a given Margin could vary depending on the size and mix of plant that are available at the time.

One of the three respondents submitted a detailed analysis and comprehensive argument on the issue of forecast error and its impact on forecast market outcomes. The response used a quantitative example to show how the outcome of LOLP (and ergo other market modelling outcomes) can be biased due to the fact that the distributions of the market outcomes are not necessarily symmetrical with respect to demand forecast error.

A fourth respondent highlighted the need to consider the error introduced by input assumptions in the context of how the LOLP values will be used.

4.1.2. Consideration of Responses

The RA's accept that the proposal to model LOLP as a function only of Margin is an approximation to the true behaviour of LOLP in the SEM, which is a time-varying relation that depends on the stochastic elements of Available Capacity, Demand and the characteristics of the transmission network.

There is a need however, to formulate a mechanism that is transparent and both easy to implement and administer, while still providing a reasonable estimate of the true underlying LOLP behaviour in the SEM. The RA's feel that the assumption of a fixed relation between LOLP and Margin is an acceptable one for the purposes of distributing payments from the Capacity Payment pot each trading Month. In terms of an operational application such as predicting the short-term security of supply, it may be that a more sophisticated process that seeks a more robust estimate of LOLP is appropriate; though this lies outside the scope of this consultation.

Regarding the variation in plant mix that could exist at a given Margin, the RA's accept that there is an assumption being made on this matter which increases the potential uncertainty in forecast outcomes. However, the RA's are of the view that the impact of the uncertainty will be minimal in real operating terms for the distribution of payments.

Regarding the forecast error, the RA's recognise the potential for bias in LOLP outcomes with regard to demand forecast error. The argument, though mathematically sound, carries less real weight with regard to the forced outage characteristics, since forced outages are a component of the system that are already modelled stochastically. The forecast error mentioned in the response thus refers to the error in calculation of the actual rates of forced outage, which carry more statistical certainty than the actual trace of availabilities (and for that matter demand) that will eventuate in reality.

While bearing the relevant merits of the respondent's argument in mind, it is the RA's view that this issue has a diminutive impact on the LOLP calculations as they are to be used in distributing payments, as the calculated outcomes are designed to distribute payments from the capacity pot relative to the relative LOLP in each trading period. Considering that these relative LOLP values will be 'flattened' as described later in Section 8 (in other words, their relativities will be exogenously changed), the impact of the demand error bias would be expected to be essentially engulfed by the flattening system and by the fact that there would be high correlation in the bias of each of the relativities.

4.2. Stacking method vs other methods

4.2.1. Responses

Of the five responses received, three were in favour of the Stacking method with some caveats, while the other two chose not to respond on the preferred methodology.

One respondent stated that the Stacking method was preferred on the condition that the error associated with assuming a fixed relationship between Margin and LOLP was shown to be minimal.

Another respondent stated that the Stacking method was preferred but requested further information about the method's pedigree. The respondent also quantitatively explored the Simulation approach and came to the conclusion that while it has merit, it is not repeatable and cannot offer the level of required precision that the Stacking method provides.

A third respondent pointed out that the Direct Calculation method is the most mathematically rigorous approach, and requested that Stacking only be used should the Direct Calculation approach prove operationally infeasible. The RA's have compiled a response to this request in the section below.

4.2.2. Consideration of Responses

Regarding the error associated with input assumptions raised by one respondent, these errors are addressed in the previous section and in the 'Calculation Frequency and Assumptions' section.

Regarding the pedigree of the Stacking method, the RA's are not aware of whether Villigarcia's method is presented in a scientific paper or is in use elsewhere. However, the RA's don't believe a strong pedigree is mandatory to its adoption in the SEM as the validity of the method is clear, as it involves only entry-level probability theory. The RA's would not expect any problem in getting the mathematics verified by an expert should this become legally necessary.

Regarding Direct Calculation, the RA's accept that this method is mathematically the most rigorous approach and would be preferred in theory.

The process of Direct Calculation would involve the following steps:

1. For each combination of forced outage state (ON / OFF) in each unit, calculate and record the resulting total availability. As mentioned in the consultation paper, in a 60 unit system this equates to $2^{60} \sim= 10^{18}$ calculations.

2. To calculate the probability that supply will be less than demand (or equivalently that total forced outage is higher than the margin), count the number of availability outcomes in the collection of 10^{18} that are below the demand requirement. Divide this number by 10^{18} to get the LOLP.

There are two computer hardware related issues associated with this process; the first relates to the time required to perform the calculations, and the other is the disk storage space required to store the outcomes for each of the 10^{18} calculations.

Having investigated these two issues, the RA's have estimated that:

1. The presently fastest supercomputer in the world[5] would take 59.4 hours to complete the calculations.

2. 7.276 million Terabytes of hard disk space would be required in the process of running the Direct Calculation.

The derivation of these estimates is provided in Appendix B. The required calculation time and storage problems make use of the Direct Calculation method infeasible in both 2007 and 2008 in the RA's view.

Regarding the other three methods (Simulation, Approximation and Alternative curves), the RA's appreciate the effort of one respondent in particular that investigated these options comprehensively before arriving at an agreement with the RA's view that these methods are inferior to the Stacking method in the context of distribution of Capacity Payments. No respondents were in favour of any of these three methods.

[5] http://www.top500.org/lists/2006/11
http://news.bbc.co.uk/1/hi/technology/4386404.stm

5. GENERATOR INPUT DATA

The RA's were minded that the LOLP curve should be defined based on:

- Generator Capacities as implemented in the determination of the Capacity Requirement for the Capacity Payment Mechanism
- Forced outage probabilities (FOPs) based on the most recent five years of historical data as applied in the determination of the Ex-ante Margin
- The Generator Set should include all conventional units that are eligible to receive Capacity Payments

5.1. Responses

One respondent highlighted the need for data to be the same as that used in Generation Adequacy Assessments and in the determination of the Capacity Requirement for the Capacity Payment Mechanism. The respondent also stated the need to include the impact of historical partial forced outages when setting the Forced Outage Probabilities, by computing an equivalent full forced outage value in energy terms.

A second respondent requested further information on how the various inputs are formulated.

5.2. Consideration of Responses

The RA's decision on the matters of Forced Outage Probabilities and Generation Capacities are as described in the summary, and the reader is referred to the corresponding documentation on the Ex-ante Margin and Capacity Requirement respectively for a full treatment of each issue.

Regarding the treatment of historical partial forced outage behaviour, the RA's intend on including this behaviour as the respondent suggests, and this method is mirrored in the approach that will be taken in neighbouring mechanisms including the determination of the Ex-ante Margin.

6. CALCULATION FREQUENCY AND ASSUMPTIONS

6.1. Calculation Frequency

In order to minimise the amount of processing and computing that will be required of the System Operators, the RA's considered that the LOLP curve would not be dynamically calculated as system conditions change on a short-term basis, but will be calculated once per trading Year.

The only exception to this would be the entry or exit of a Market Participant, upon which the curve would be recalculated and published a sufficient amount of time prior to the entry or exit in question.

6.1.1. Responses

One respondent was of the view that the curve should only ever be calculated once per year regardless of entry and exit in the market.

A second respondent agreed with the RA's suggested view that the curve should be calculated once per Year except when market entry / exit warrants re-calculation.

The other respondents did not directly comment on this issue.

6.1.2. Consideration of Responses

Having considered the responses, the RA's have decided that an acceptable trade-off between frequency of computation and accuracy is to adopt the suggested methodology whereby the calculation will take place once per trading Year, with re-calculation for entry or exit of market Generator Units of Registered Capacity 50MW or more.

6.2. Assumptions about Generator Set in Calculation

Given the calculation frequency as described in the section above, it is necessary to choose a system state upon which the curve can be calculated. The term 'system state' in this sense refers to the make-up of the generation stack of units that is to be assumed when calculating the curve.

The RA's considered the assumption that all conventional market generators would be assumed to be 'in operation' (that is, not on scheduled maintenance) for the purposes of calculating the curve.

6.2.1. Responses

One respondent requested further justification for the assumption that no plant is on scheduled maintenance when calculating the curve.

It was the view of another respondent that failure to take account of planned outages will result in non-cost-reflective signals.

6.2.2. Consideration of Responses

This issue really ties in with two over-arching decision issues; the first being the decision to model LOLP only as a function of Margin, thus ignoring the actual Capacity and Demand characteristics that prevail; the second being the decision as above to only compute a single curve that will apply in all circumstances during the year.

Given these two over-arching decisions, it is necessary to choose a system state which is a fair and un-biased (as far as possible) representation of the generation stack for the purpose of calculating a single curve.

Because real loss of load is most likely to occur in winter, this lends justification to the assumption that the plant mix is fully available (not on scheduled outage), as it is expected that few or no units will be on scheduled outage during the peak annual load periods in winter.

Regarding bias, assuming that no units are on scheduled outage is a means of ensuring that there is no specific bias in the approach. If in theory, the RA's were to assume that some plant were on scheduled outage, there would be the subjective question of which units to turn off.

The RA's consider that the respondents' comments on this issue are really related to the over-arching assumptions and that in the context of the decisions made on those assumptions, there is probably little opposition to the decision to base the single static LOLP curve on the assumption that there is no plant on scheduled maintenance.

7. SEPARATE LOLP CURVES FOR VARIABLE AND EX-POST

7.1. Responses

Of the five responses received, three were in favour of the use of a single LOLP curve for both the Variable and Ex-post components of the Capacity Payment Mechanism. The remaining two elected not to comment on this matter.

7.2. Consideration of Responses

It is the RA’s view that this issue ties in very closely with the issue of flattening of Capacity Payments as described in the next section.

Given the comments received, the RA’s decision is to apply the same curve to both components.

8. Flattening of the LOLP Curve / Capacity Payments

8.1. Background

The Consultation Paper discusses the prospect of flattening the LOLP curve in order to overcome the problem of potentially assigning large proportions of the variable and ex-post capacity pot money to single periods which, despite carrying low LOLP values, are orders of magnitude higher than the LOLP in other periods and thus receive a relatively large proportion of the pot, leaving only small amounts be distributed to the remaining periods.

8.2. Responses

Of the five respondents, three indicated that they were in favour of flattening of payments, with the remainder did not comment on the issue.

8.3. Consideration of Responses

Previously the RA's were not minded to pursue flattening due to the fact that using a cut-off flattening of the curve sacrificed the inverse relationship between Margin and Payment for periods in which the Margin is beyond the cut-off point. Given the responses however, an additional investigation was conducted to determine if a method existed whereby the spikes that result from using the unflattened curve could be more effectively smoothed without compromising the inverse relationship between Margin and Payment.

The method developed by the RA's is called a Power Factor (PF) weighting technique. It flattens the payments by weighting the trading periods by their respective LOLPs, raised to a power between 0 and 1.

Under current design, without flattening, the proportion of money (PayRatio) allocated to period P is

$$\mathbf{PayRatio}_{\mathbf{P}} = \frac{\mathbf{LOLP}_{\mathbf{P}}}{\sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{LOLP}_{\mathbf{i}}}$$

Applying a Power Factor involves modifying the equation as follows:

$$\mathbf{PayRatio}_{\mathbf{P}} = \frac{\left(\mathbf{LOLP}_{\mathbf{P}}{}^{a}\right)}{\sum_{\mathbf{i=1}}^{\mathbf{n}}\left(\mathbf{LOLP}_{\mathbf{i}}{}^{a}\right)}$$

where *a* is the Power Factor. Note that setting *a* to 1.0 results in the original equation, so the effect of setting *a* to 1.0 is to simply not flatten the payment ratios.

The desire is to keep some volatility in the payments to signal the need for availability during periods of system stress, but at the same time provide a smooth stream of payments over the course of the month. To achieve this objective, the RA's have decided to implement a PF of 0.35, following simulation studies of the impact that various PFs have on the distribution of payments.

APPENDIX A – RESPONSE TO DETAILED COMMENTS

This Appendix sets out the comments received from respondents to the Consultation document and the responses from the Regulatory Authorities. The comments are grouped by subject matter for ease of consideration. Note that only points of contention are raised in this summary, comments made which agree with proposals or analysis set out in the consultation are not included.

Document Title:	**Loss of Load Probability Curve for Capacity Payment Mechanism**
Document Ref Number:	AIP/SEM/07/10
Comments to be returned by:	13/03/2007
Comments returned to:	Paul Bell (paul.bell@ofreg.gov.ni)
Document Author:	Jos Ijpelaar

Respondee	**Heading / Comments**	**Response**
	Introduction & Summary	
Synergen	No adjustments should be made to the LOLP curve within year in any circumstances.	The RA's are of the view that updates to the LOLP curve would be warranted by step changes in the system composition, including the entry or exit of a Generator Unit. Re-calculation of the LOLP curve upon the event of new entry or exit from the SEM will be a relatively straight-forward procedure for the System Operator to conduct.

ESB Independent Energy	Changing the LOLP curve during the year will increase the risk to generators without sending any new signals that generators can respond to.	See above. Also, the RA's disagree that such adjustment of the curve would increase risk to participants as the LOLP curve will not drastically change shape upon recalculation or become a source of uncertainty in the short-term. The alternative of re-calculation on an annual basis only would be a scenario in which the LOLP curve was discretely updating anyway. The changes at the annual boundaries would be more significant than if the curve were to be more frequently updated as outlined in this decision document.
NIE	Failure to take account of planned outages (*in determining the LOLP curve*) will result in non-cost-reflective signals.	The RA's are of the view that setting a fixed LOLP curve that will apply in all circumstances is an acceptable trade-off between dynamic computation overhead and precision for the purpose of the distribution of Capacity Payments. It also grants an added degree of transparency to payment distributions. In setting the conditions for the calculation of the LOLP curve, the assumption that no plant is on planned outage is a good set-point because this should be close to the true nature of the system during the winter months when margins are likely to be at their minimum points for the year.

APPENDIX B – DIRECT CALCULATION INVESTIGATION

In November 2006 the fastest supercomputer in the world was the BlueGene/L system:

http://www.top500.org/lists/2006/11
http://news.bbc.co.uk/1/hi/technology/4386404.stm

This computer has thousands of processors and is housed in a large research facility. It is capable of a processing speed of 280.6 Tera-FLOPS. This means the computer can perform 280.6×10^{12} floating-point operations per second.

An example of a floating-point operation is the addition or multiplication of two numbers. For each availability calculation, the availabilities of each unit (60 values) must be added together, so there are 60 floating point operations per availability calculation.

The number of floating-point operations required to perform the complete Direct Calculation is thus = 6×10^{19}

The time required for BlueGene/L to perform the complete Direct Calculation is then = $6 \times 10^{19} / (280.6 \times 10^{12}) = 0.02138 \times 10^{7}$ seconds = 59.4 hours.

The total availability of each scenario is a mega-watt value that would likely require no more than eight characters (for example, a total availability of 5045.325 megawatts occupies eight characters including the decimal point while 5045.3 occupies six characters).

Using the storage required for ASCII characters on a Windows machine as a reference, one character occupies one byte of hard disk space[6]. This means that there are 8 bytes required per calculation so the storage space required is 8×10^{18} bytes.

This equates to 7.276 million Terabytes of hard disk space.

[6] There are eight bits in a byte and it is the case that the digits 0 through 9 and the decimal point can be represented completely by just four bits rather than eight. A four-bit storage system would in theory halve the storage requirement presented in these calculations.

The hard disk space is at least six orders of magnitude too high to be practical for present technology. However, it may be that the Direct Calculation method could be iterated such that the values on the disk were condensed down to a discrete probability table and the storage space wiped before commencing a new cycle of calculations and disk usage. The 'discrete-isation' associated with this technique would however largely negate the value of doing Direct Calculation in the first place, since fast discrete point-based methods already exist (such as the Stacking methodology).

Given that conventional computing power available to the SO's (or their consulting contractors) will be several orders of magnitude slower than BlueGene/L, the time required to perform the calculations is certainly too long. Even a stand-alone supercomputer cluster 100 times slower than BlueGene/L would take around 8 months to perform the calculations and would be prohibitively expensive to procure.

It is important to bear in mind that both the time and storage space required doubles with every addition of a new generator unit. This means that the times and storage calculated here would double were a '61st' unit to enter the system. As such, growth in SEM participation would act to hamper the benefits that Direct Calculation would see in the form of improved processor speed and storage technology as time goes on.