# BRIEF ON AUTOMATION OF NEGATIVE RESIDUE MANAGEMENT

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| PREPARED BY: | Electricity Market Monitoring |
| VERSION: | 2.0 |
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FINAL

# Contents

# Version Release History

| VERSION | DATE | BY | CHANGES |
|---|---|---|---|
| 0.1 | 01-05-2012 | Valerie Lim | Initial draft |
| 1.0 | 08-06-2012 | Duncan Swijnenburg | Change of template |
| 1.1 | 09-07-2014 | Valerie Lim | Clarification of the NRM process |
| 2.0 | 01-02-2018 | Valerie Lim | Publication of NRM inputs |

# Disclaimer

# Glossary

| ABBREVIATION | TERM |
|---|---|
| AEMO | Australian Energy Market Operator Ltd |
| CVP | Constraint Violation Penalty |
| DI | Dispatch Interval |
| LHS | Left Hand Side of constraint |
| NEM | National Electricity Market |
| NR$ | Negative Residue in dollars |
| NRM | Negative Residue Management |
| NRM_DI_AMT | Estimated negative residue for the current trading interval. Based on accumulated residue for all dispatch intervals of the current trading interval, extrapolated to the end of the trading interval) |
| RHS | Right Hand Side of constraint |

# 1 Background

AEMO is to use reasonable endeavours to cease the accumulation of negative inter-regional settlement residues in the NEM when this accumulation reaches or exceeds the negative residue accumulation threshold of -$100,000 (as of 1 July 2010).

AEMO's control room normally acts in the dispatch timeframe, manually constraining flow on the relevant directional interconnector[1] to cease any further accumulation. However, during times of high workload or when managing power system security is the highest priority, this may not always happen expeditiously.

To ensure initial action is taken once the accumulated negative residue has, or is estimated to, reach or exceed the threshold, AEMO has implemented an automated negative residue management process. This process activates/deactivates relevant Negative Residue Management (NRM) constraint equations by un-swamping/swamping them as soon as the threshold is reached/exceeded or positive residues are now accumulating. The aim of the NRM constraint equations is to prevent further accumulation of negative residues by reducing the counter-price flow on the relevant directional interconnector. This management will also be reflected in the pre-dispatch time frame for up to two trading intervals (TIs).

The automatic NRM constraint equations will use the latest accumulation values available from dispatch. The accumulation amount, relevant to the affected directional interconnector, is based on residues in the previous TIs and an estimate for the current TI. The current TI estimate is based on an average of the dispatch interval (DI) quantities so far in the current TI, extrapolated to the end of the TI. At the last DI of each TI (or when dispatch results are not available) pre-dispatch residues for the next TI (based on 30 minutes pre-dispatch solution) are assessed and included in the accumulation amount.

Since the implementation of the automated process, the AEMC has conducted a review of AEMO's management of negative inter-regional settlements residue. Its Final Report, which was published on 20 February 2014, recommends for AEMO to publish the estimate of negative residues in real-time. This data is available as of 27 July 2015.

This document provides an overview of the process and the NRM data that is published. In this document, NRM data items are referenced to the relevant field name in the DISPATCH.NEGATIVE_RESIDUE table, shown in italics.

# 2 Accumulation of Negative Residue

The accumulation of negative residue for a directional interconnector commences from the first DI that residues across the directional interconnector become negative (*NEGRESIDUE_CURRENT_TI*).

At any DI when the accumulated negative residue (*CUMUL_NEGRESIDUE_AMOUNT*) reaches or exceeds the threshold of -$100,000, AEMO's automated process will start managing to reduce the negative residue (unless the underlying dispatch prices are subject to review[2]).

The accumulated negative residue will be reset to zero when the residue for the current TI is either zero or positive.

[1] Flow on a directional interconnector refers to the net boundary flow on all parallel regulated interconnectors towards a certain region

[2] Automated procedures to identify dispatch intervals subject to MII (http://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Dispatch/Policy_and_Process/2017/Automated-Procedures-For-Identifying-Dispatch-Intervals-Subject-to-Review.docx)

# 3 Negative Residue Management Process

## 3.1 Negative Residue Management Constraint Equations

The NRM process involves a permanently invoked set of constraint equations to manage flow on each directional interconnector, where the NRM constraint equation is named ‘NRM_<Directional Interconnector ID>’ as shown in Table 1.

For example, constraint equation ‘NRM_NSW1_QLD1’ manages the net flow from New South Wales to Queensland over the ‘NSW1-QLD1’ and ‘N-Q-MNSP1’ interconnectors.

Typically, NRM constraint equations are not active in the system (swamped out with a large Right Hand Side (RHS) value).

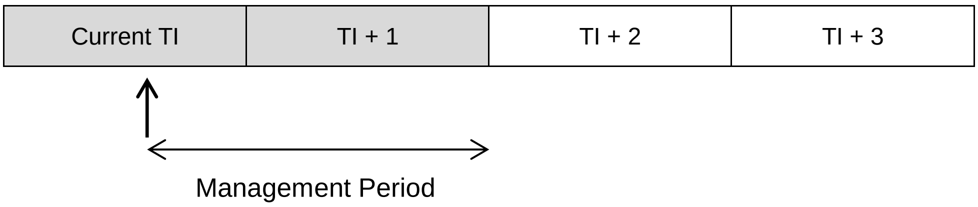
*Table 1: NRM constraint equations*

| Constraint Equation | Interconnector flow direction |
|---|---|
| NRM_NSW1_QLD1 | New South Wales to Queensland |
| NRM_QLD1_NSW1 | Queensland to New South Wales |
| NRM_NSW1_VIC1 | New South Wales to Victoria |
| NRM_VIC1_NSW1 | Victoria to New South Wales |
| NRM_SA1_VIC1 | South Australia to Victoria |
| NRM_VIC1_SA1 | Victoria to South Australia |

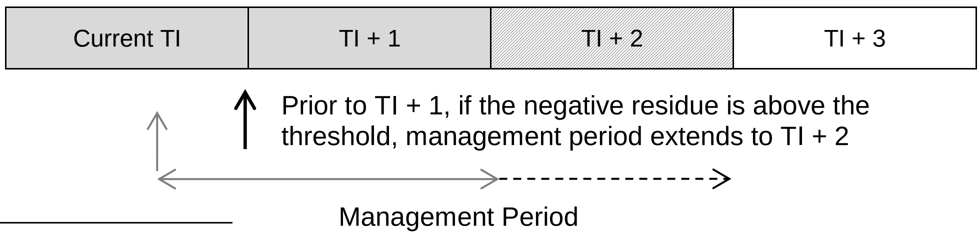
These constraint equations have the form Left Hand Side (LHS) ≤ RHS where the directional interconnectors are the controllable variables on the LHS. The constraint violation penalty (CVP) factor for each of these equations is set to 2[3]. AEMO’s control room will block the relevant constraint equation and manually set the CVP when a different factor is required.

## 3.2 Negative Residue Management Period

When the threshold is reached or exceeded the relevant NRM constraint equations will be automatically activated to manage the accumulated negative residue from the next dispatch interval to the end of the following trading interval (TI + 1). Within this management period, NRM constraint equations can be temporarily activated and de-activated when certain conditions are met, as discussed in section 3.3.




If the accumulated negative residue before the start of a new trading interval[4] (TI + 1) remains above the threshold, the management period is extended for another trading interval (TI + 2).




[3] Schedule of Constraint Violation Penalty Factors. (http://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Congestion-Information/2016/Schedule-of-Constraint-Violation-Penalty-factors.pdf )

[4] This is determined after the dispatch run for the last DI of the current TI, and based on the actual accumulated negative residue plus the estimated residue for the next TI of the latest pre-dispatch run

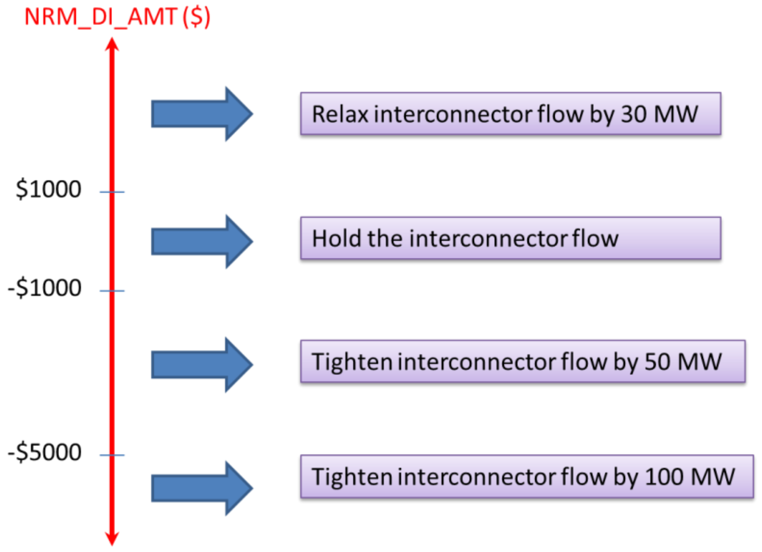
### 3.3 Management of Directional Interconnector Flow

The management process uses a NRM constraint equation to progressively constrain off counter-priced flow in pre-defined steps, with the size of the step dependent on the amount, and sign, of the estimated residue for the current TI, defined as 'NRM_DI_AMT' *(NEGRESIDUE_CURRENT_TI in the DISPATCH.NEGATIVE_RESIDUE table)*.

Depending on the negative value of 'NRM_DI_AMT' the constraint equation will constrain the directional interconnector with either a more aggressive or a more conservative step. If the 'NRM_DI_AMT' is positive, beyond a defined positive limit, the NRM constraint equation will relax the directional interconnector flow by another pre-defined step. These step adjustments are automatically carried out while ensuring that the directional flow does not reverse.

Figure 1 shows a typical example of the different thresholds of NRM_DI_AMT and the corresponding actions taken by the NRM constraint equation with the different steps sizes (MW).

*Figure 1: Example of negative residue management process*




The current step sizes and thresholds for 'NRM_DI_AMT' (NR$) for each directional interconnector are listed in Table 2 and will be continually reviewed on a half-yearly basis in order to improve the NRM process.

*Table 2: NRM Constraint equation – RHS step change design*

| NRM_DI_AMT (NR$) / Interconnector constraint | NR$ < -5000 | -5000 <= NR$ < -1000 | -1000 <= NR$ < 1000 | NR$ >= 1000 |
|---|---|---|---|---|
| NRM_NSW1_QLD1 | -100 MW | -50 MW | 0 MW | 30 MW |
| NRM_QLD1_NSW1 | -100 MW | -50 MW | 0 MW | 30 MW |
| NRM_NSW1_VIC1 | -100 MW | -50 MW | 0 MW | 30 MW |
| NRM_VIC1_NSW1 | -100 MW | -50 MW | 0 MW | 30 MW |
| NRM_VIC1_SA1 | -50 MW | -30 MW | 0 MW | 30 MW |
| NRM_SA1_VIC1 | -30 MW | -25 MW | 0 MW | 25 MW |

Asymmetrical step sizes - where larger steps are applied for negative residues and smaller steps are applied for positive residues - were introduced to minimise the negative residue accumulation and to avoid oscillations of the target interconnector flow over consecutive DIs. If the relaxation and tightening introduced by the NRM constraint equations were applied symmetrically, the target interconnector flow can oscillate over a series of consecutive DIs. When oscillations occur, it will be difficult to return the target interconnector flow to a stable state where there will be zero residues.

### 3.4 Temporary Suspension of Negative Residue Management within the Management Period

Within a management period, the NRM constraint equation will continue to manage the accumulation of negative residue until one of the following conditions is met:

- For the last three DIs, the NRM constraint equation has not bound (*DI_NOTBINDING_COUNT*) and non-negative NRM_DI_AMT (that is, *NEGRESIDUE_CURRENT_TI = 0*) were occurring.
- For the last three DIs, the NRM constraint equation has violated (*DI_VIOLATED_COUNT*) and non-negative NRM_DI_AMT (that is, *NEGRESIDUE_CURRENT_TI = 0*) were occurring.
- AEMO's control room manually intervenes in the process by blocking the NRM constraint equation (*NRMCONSTRAINT_BLOCKED_FLAG*).

Temporary suspension of the NRM within a management period will cease when NRM_DI_AMT (NEGRESIDUE_CURRENT_TI) exceeds -$1,000.

### 3.5 End of Management Period

The management of negative residues ceases at the end of the management period for a directional interconnector when its accumulated negative residue is below the threshold of -$100,000 and there are no further extensions to the management period.

### 3.6 Notices to Participants

The NRM process automatically issues Market Notices when an NRM constraint equation becomes active to inform participants of the management process. This will be followed by another Market Notice when the NRM equation is no longer active to inform participants that the management process has ceased.

## 4 Publication of inputs for Negative Residue Management

The publication of inputs for NRM constraint equations are available from:

- Data Interchange in the DISPATCH_NEGATIVE_RESIDUE table, and
- AEMO's website:
  - http://nemweb.com.au/Reports/CURRENT/DISPATCH_NEGATIVE_RESIDUE/ (Current month, one file per DI)
  - http://nemweb.com.au/Reports/ARCHIVE/Dispatch_Negative_Residue/ (Previous months, one file per day)

The table/file is populated for each 5-minute dispatch interval, displaying only residues that are negative for each directional interconnector. It provides several key information including:

- Active management period (*NRM_ACTIVATED_FLAG*)

- Negative residue amount (*CUMUL_NEGRESIDUE_AMOUNT, CUMUL_NEGRESIDUE_PREV_TI*, *NEGRESIDUE_CURRENT_TI* and *NEGRESIDUE_PD_NEXT_TI*)
- Dispatch interval when the management will cease (*EVENT_DEACTIVATED_DI*)

Appendix A describes the data in the DISPATCH_NEGATIVERESIDUE table.

# 5 Appendix A

| | |
|---|---|
| Name | DISPATCH |
| Comment | Results from a published Dispatch Run |

### Table: NEGATIVE_RESIDUE

| | |
|---|---|
| Name | NEGATIVE_RESIDUE |
| Comment | Shows the inputs provided to the Negative Residue Constraints in the Dispatch horizon |
| Visibility | Public |

| Field Name | Data type | Mandatory | Comment |
|---|---|---|---|
| SETTLEMENTDATE | DATE | Yes | Dispatch Interval to which the results from the NRM apply in Dispatch |
| NRM_DATETIME | DATE | Yes | The time that the NRM process determines residues |
| DIRECTIONAL_INTERCONNECTORID | VARCHAR2(30) | Yes | Directional interconnector id (see table 2) |
| NRM_ACTIVATED_FLAG | NUMBER(1,0) | No | Is 1 if NRM constraint applies for SettlementDate, else is 0 |
| CUMUL_NEGRESIDUE_AMOUNT | NUMBER(15,5) | No | Accumulated negative residue amount used to trigger an NRM event and apply an NRM constraint |
| CUMUL_NEGRESIDUE_PREV_TI | NUMBER(15,5) | No | Accumulated negative residue amount for the previous trading interval |
| NEGRESIDUE_CURRENT_TI | NUMBER(15,5) | No | Negative residue amount for the current trading interval |
| NEGRESIDUE_PD_NEXT_TI | NUMBER(15,5) | No | Negative residue amount for the next trading interval of the latest pre-dispatch |
| PRICE_REVISION | VARCHAR2(30) | No | Subject To Review, Indeterminate, Accepted or Rejected |
| PREDISPATCHSEQNO | VARCHAR2(20) | No | Pre-dispatch sequence number |
| EVENT_ACTIVATED_DI | DATE | No | The starting DI when NRM event is active |
| EVENT_DEACTIVATED_DI | DATE | No | The finishing DI when NRM event stops being active. |
| DI_NOTBINDING_COUNT | NUMBER(2,0) | No | Count of the number of consecutive DIs that the relevant NRM constraint is not binding (0-3) |
| DI_VIOLATED_COUNT | NUMBER(2,0) | No | Count of the number of consecutive DIs that the NRM constraint is violated (0-3) |
| NRMCONSTRAINT_BLOCKED_FLAG | NUMBER(1,0) | No | 1 if NRM constraint is blocked, else 0 |