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# AUTOMATION OF NEGATIVE RESIDUE MANAGEMENT

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July 2021

# Important notice

## PURPOSE

The Australian Energy Market Operator (AEMO) ~~has published this document publishes the Brief on Automation of Negative Reside Management~~ to provide information ~~about on~~ the approach ~~used~~ to minimise the accumulation of negative inter-regional settlement residues in the National Electricity Market, as at the date of publication. ~~The Rules and the National Electricity Law (Law) prevail over this document to the extent of any inconsistency. Information made available after this date may have been included in this publication where practical.~~

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## VERSION CONTROL

Version	Effective date	Changes
0.1	01-05-2012	<ul style="list-style-type: none"><li>• Initial draft</li></ul>
1.0	08-06-2012	<ul style="list-style-type: none"><li>• Change of template</li></ul>
1.1	09-07-2014	<ul style="list-style-type: none"><li>• Clarification of the NRM process</li></ul>
2.0	01-02-2018	<ul style="list-style-type: none"><li>• Publication of NRM inputs</li></ul>
3.0	01-07-2021	<ul style="list-style-type: none"><li>• Moved to new template</li><li>• Updated for 5MS</li></ul>

# Contents

<b>1.</b>	<b>Background</b>	<b>4</b>
<b>2.</b>	<b>Accumulation of Negative Residue</b>	<b>4</b>
<b>3.</b>	<b>Negative Residue Management Process</b>	<b>5</b>
3.1	Negative Residue Management Constraint Equations	5
3.2	Negative Residue Management Period	5
3.3	Management of Directional Interconnector Flow	6
3.4	Temporary Suspension of Negative Residue Management within the Management Period	8
3.5	End of Management Period	8
3.6	Notices to Participants	8
<b>4.</b>	<b>Publication of inputs for Negative Residue Management</b>	<b>8</b>
<b>5.</b>	<b>Appendix A</b>	<b>9</b>

# Tables

Table 1	NRM constraint equations	5
Table 2	NRM Constraint equation – RHS step change design	7
Table 3	DISPATCH	9
Table 4	NEGATIVE_RESIDUE	9
Table 5	Field Names	9

# Figures

Figure 1	Negative Residue Management Period	6
Figure 2	Negative Residue Management Period extension	6
Figure 3	Example of negative residue management process	7

# 1. Background

AEMO ~~is to use reasonable endeavours~~ uses automated constraints to ~~cease~~ limit 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<sup>1</sup> 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.~~

~~Note that this document uses many terms that are defined in the National Electricity Rules, which are intended to have the same meaning here.~~

To ensure limitation measures are initiated ~~initial action is taken~~ once the accumulated negative residue has, or is ~~expected~~ estimated to, reach or exceed the threshold, AEMO has implemented an automated negative residue management process. This process activates ~~/or~~ 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~~ start 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 in real time. ~~This action management will also be reflected~~ NRM constraint equations may also be used in the pre-dispatch time frame for up to the next two trading 30-minute periods/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 30-minute period ~~TIs~~ and ~~an future- an~~ estimate of current 30-minute period residue for. Estimates of future the current 30-minute period residues is are based on an average of ~~all six~~ the available trading intervals (TIs) in the next current 30-minute period. A 30-minute period is a period that begins at the hour or half hour mark (e.g. 1200-1230 or 1230-1300). At the last TI of the 30-minute period (e.g. 1225-1230 for the 1200-1230 interval/period), or when TI results are not available, pre-dispatch residues for the next 30-minute period are assessed (based on using 30-minute pre-dispatch) and included in the accumulation amount. ~~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<sup>2</sup> 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.

~~Note that this document uses many terms that are defined in the National Electricity Rules, which are intended to have the same meaning here.~~

## 2. Accumulation of Negative Residue

<sup>1</sup> Flow on a directional interconnector refers to the net boundary flow on all parallel regulated interconnectors towards a certain region

The accumulation of negative residue for a directional interconnector commences from the first DTI that residues across the directional interconnector become negative (*NEGRESIDUE\_CURRENT\_TI*).

At any DTI 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<sup>2</sup>).

The accumulated negative residue will be reset to zero when the residue for the current 30-minute period ~~average of the six trading intervals over a 30-minute period~~ *current TI* is either zero or positive.

### 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<sup>3</sup>. AEMO’s control room will block the relevant constraint equation and manually set the CVP when a different factor is required.

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

#### 3.2 Negative Residue Management Period

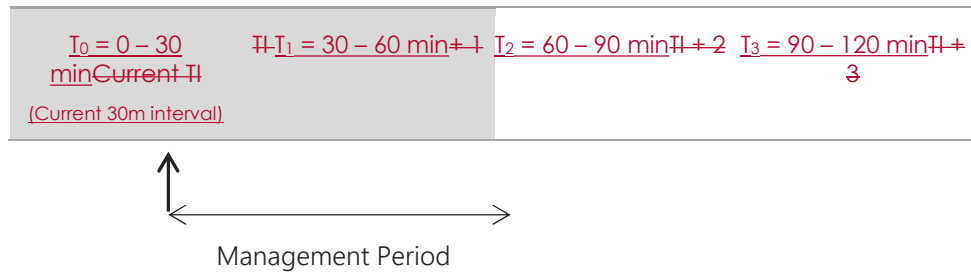
~~The Negative Residue Management Period is assessed at the start of every 30-minute period.~~ When the threshold is reached or exceeded the relevant NRM constraint equations will be automatically activated to manage the accumulated negative residue from the next dispatch-trading interval to the end of the following

<sup>2</sup> Automated procedures to identify dispatch intervals subject to MII ([https://aemo.com.au/-/media/Files/Stakeholder\\_Consultation/Consultations/NEM-Consultations/2019/Dispatch/Automated-procedures-for-identifying-intervals-subject-to-review---latest.pdf](https://aemo.com.au/-/media/Files/Stakeholder_Consultation/Consultations/NEM-Consultations/2019/Dispatch/Automated-procedures-for-identifying-intervals-subject-to-review---latest.pdf))

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

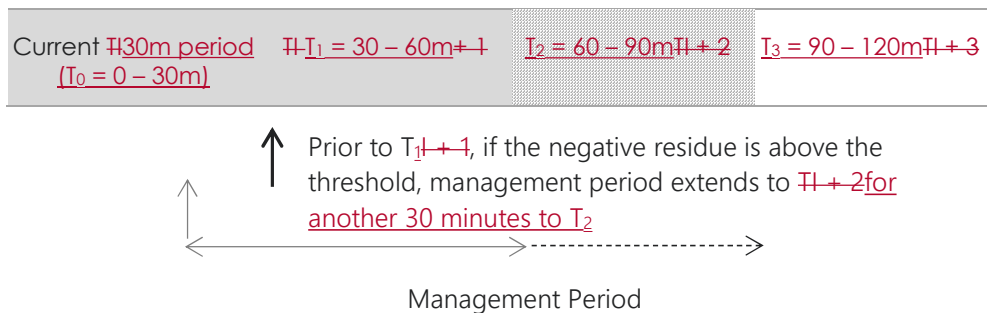
30-minute period, trading interval (TI + 1). Within this management period, NRM constraint equations can be temporarily activated and de-activated when certain conditions are met, as discussed in section 3.3.

**Figure 1 Negative Residue Management Period**



If the accumulated negative residue before the start of a new trading interval 30-minute period<sup>4</sup> (TI + 1) remains above the threshold, the management period is extended for another trading interval (TI + 2) 30-minute period.

**Figure 2 Negative Residue Management Period extension**



### 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*).

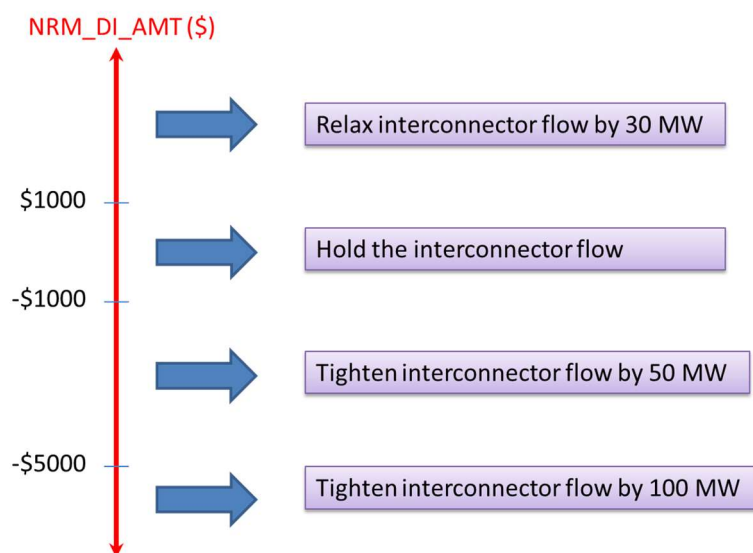
Depending on the negative value of 'NRM\_DI\_AMT' the constraint equation will constrain the directional interconnector with either a more aggressive or a more conservative step. If the 'NRM\_DI\_AMT' is positive, beyond a defined positive limit, the NRM constraint equation will relax the directional interconnector flow by

<sup>4</sup> This is determined after the dispatch run for the last  $\Delta T_{TI}$  of the current 30 minute period, and based on the actual accumulated negative residue plus the estimated residue for the next 30 minute period of the latest pre-dispatch run

another pre-defined step. These step adjustments are automatically carried out while ensuring that the directional flow does not reverse.

Figure 3~~Figure 4~~ 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 3 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 ~~IDs~~<sup>DTIs</sup>. 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 ~~IDs~~<sup>DTIs</sup>. 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 **IDs**, 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 **IDs**, 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 ~~that NRM is active of the management process~~. This will be followed by another Market Notice ~~to inform participants when the management period has ended when the NRM equation is no longer active to inform participants that the management period 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/](http://nemweb.com.au/Reports/CURRENT/Dispatch_Negative_Residue/) (Current month, one file per **ID**)
  - [http://nemweb.com.au/Reports/ARCHIVE/Dispatch\\_Negative\\_Residue/](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\_NEGATIVE\_RESIDUE table.



## 5. Appendix A

**Table 3** DISPATCH

Name	DISPATCH
Comment	Results from a published Dispatch Run

**Table 4** NEGATIVE RESIDUE

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

**Table 5** Field Names

Field Name	Data type	Mandatory	Comment
SETTLEMENTDATE	DATE	Yes	<u>Dispatch-Trading</u> 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 <u>trading-30-minute interval period</u>
NEGRESIDUE_CURRENT_TI	NUMBER(15,5)	No	Negative residue amount for the current <u>trading-30-minute interval period</u>
NEGRESIDUE_PD_NEXT_TI	NUMBER(15,5)	No	Negative residue amount for the next <u>trading-30-minute interval period</u> 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 <u>DI-TI</u> when NRM event is active
EVENT_DEACTIVATED_DI	DATE	No	The finishing <u>DI</u> when NRM event stops being active.
DI_NOTBINDING_COUNT	NUMBER(2,0)	No	Count of the number of consecutive <u>DI</u> s that the relevant NRM constraint is not binding (0-3)
DI_VIOLATED_COUNT	NUMBER(2,0)	No	Count of the number of consecutive <u>DI</u> s that the NRM constraint is violated (0-3)
NRMCONSTRAINT_BLOCKED_FLAG	NUMBER(1,0)	No	1 if NRM constraint is blocked, else 0