

# 5-MINUTE PRE-DISPATCH DEMAND FORECASTING USING HISTORICAL DEMAND CHANGE PROFILE BUSINESS SPECIFICATION

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## Distribution

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## 1. Reference

### 1.1 Abbreviations

ABBREVIATION	EXPLANATION
5MPD	Five Minute Pre-Dispatch
MMS	Market Management System; software, hardware, network and related processes to implement the NEM; an AEMO department responsible for maintaining the system
NEM	National Electricity Market
NEMDE	National Electricity Market Dispatch Engine (aka Market Solver)
NER/ Rules	National Electricity Rules

## 2. Introduction

### 2.1 Overview

This Business Specification outlines modifications to AEMO's 5-minute Pre-dispatch (5MPD) demand forecasting methodology in order to improve its demand forecasting accuracy.

### 2.2 Business Drivers

Work conducted by AEMO's 5MPD Process Review Group shows that the demand forecasting performance of the 5MPD process was not satisfactory, resulting in large demand and therefore price forecast errors observed, particularly where demand peaks occur part-way through a half-hourly trading interval.

In order to address this problem AEMO's 5MPD Process Review Group, comprising a key set of market participants, looked at the possible ways to improve the 5MPD demand forecasting accuracy. The best option identified among those discussed was to apply a time-of-day based average percentage demand change profile to the current demand, based upon the average historical demand change data over the previous two weeks. Extensive analysis demonstrated that this method produced more accurate demand forecasting results than the forecasting method used at that time, which was based on the half-hourly Pre-dispatch demand forecast. The 5MPD Review Group had thus recommended that this new forecasting method be implemented into AEMO's Production systems.

#### 2.2.1 Benefits

The benefits of the changes are:

- Improvement in 5MPD demand forecasting accuracy for all regions, particularly in periods where demand spikes occur within a half-hourly interval;

- Better utilisation of 5MPD schedule information by market participants.

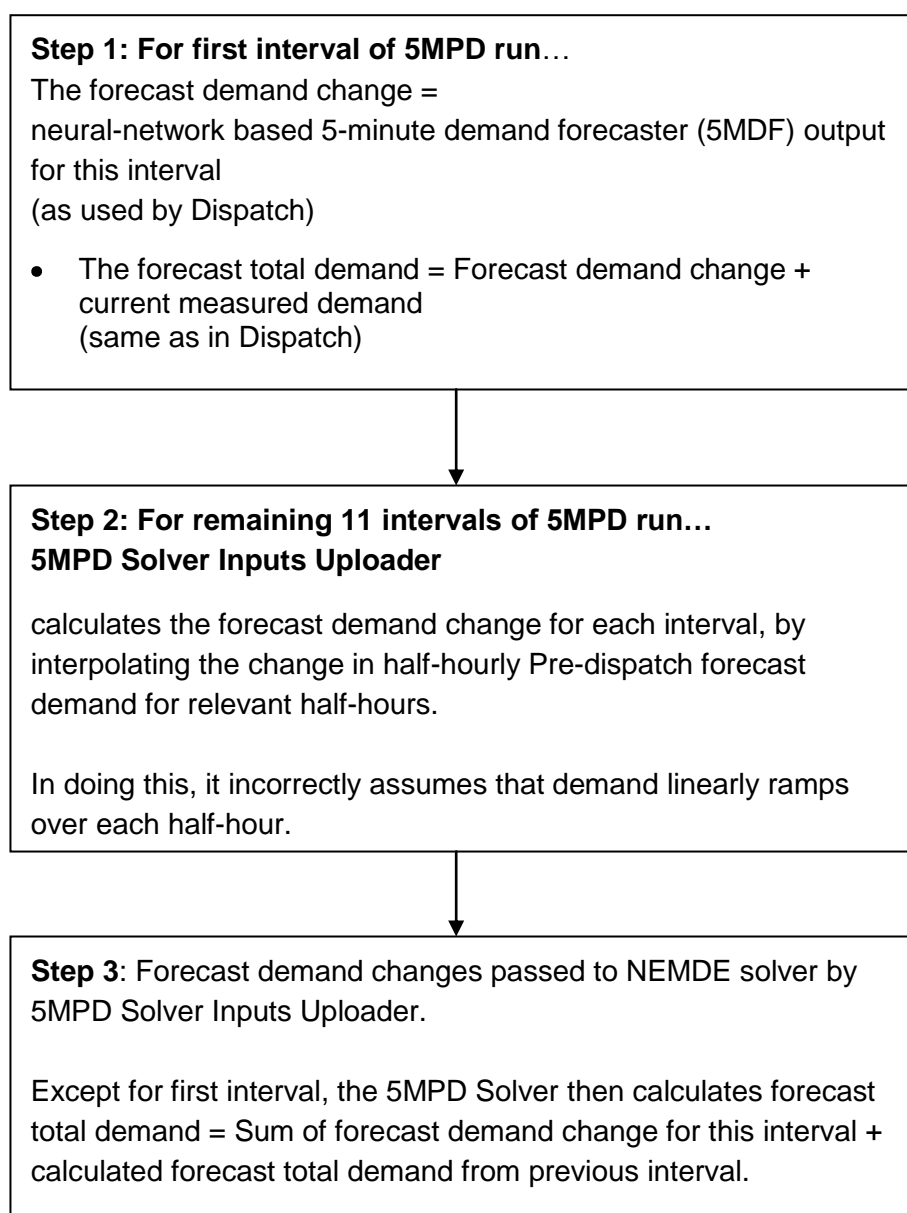
### **3. Previous Status Summary**

Previously, the 5MPD Process used the half-hourly demand forecasts (as used by the Pre-dispatch process) to produce demand forecasts. For every 5MPD run, the 5MPD schedule provided regional demand and price forecasts for each of the twelve 5-minute intervals over the next hour.

The previous demand forecasting process in 5MPD is described in detail below.

### 3.1 Context Diagram

The following diagram describes the previous demand forecasting process in 5MPD:



### 3.2 Previous Process

#### 3.2.1 Outline

As shown in above Diagram, the demand forecasting in 5MPD process previously operated as follows:

1. 5MPD used the demand forecast produced by Dispatch demand forecaster for the first interval of every 5MPD run;

2. For the remaining eleven 5-minute intervals, 5MPD process used the Pre-dispatch demand forecast for relevant half-hours to produce demand forecasts by assuming that demand changes linearly within each half-hour.

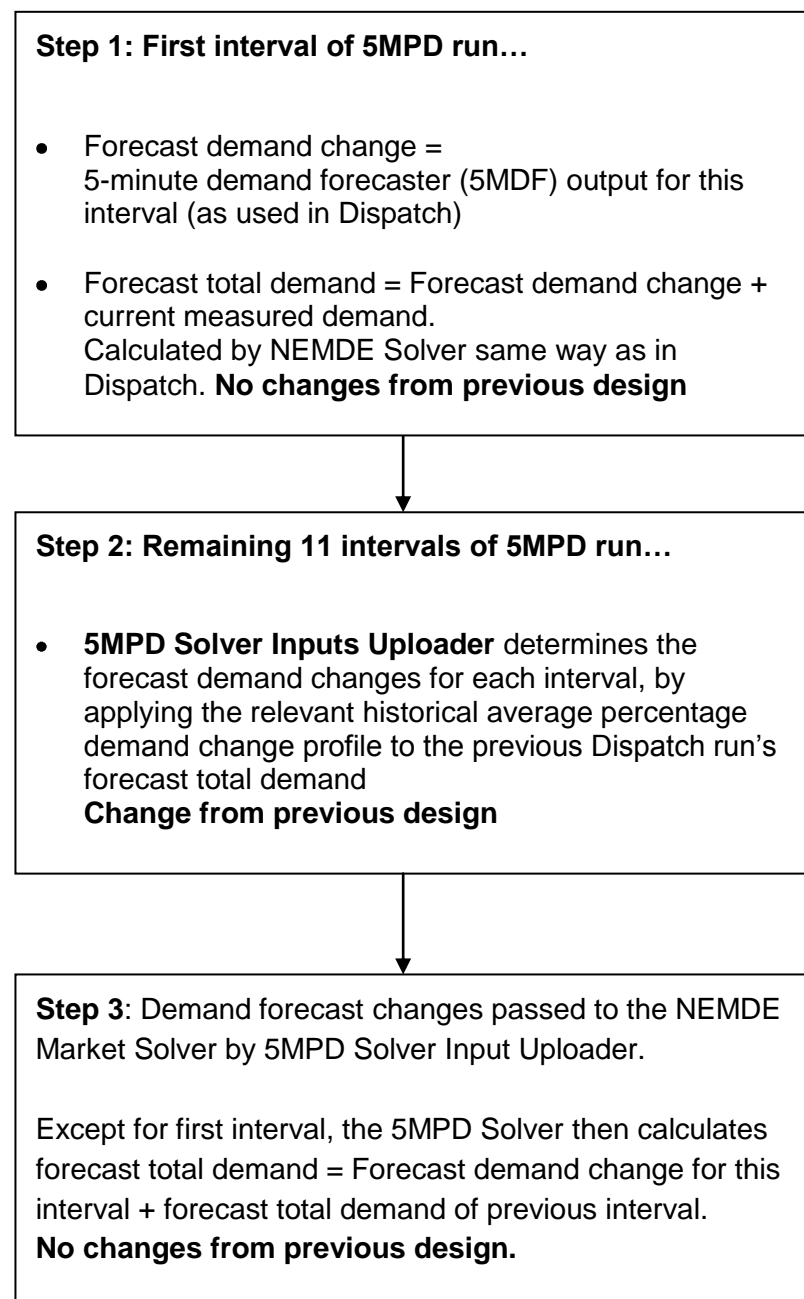
The above process applied to all NEM regions.

## 4. New Process

The new method is described in detail as follows.

### 4.1 Context Diagram

The following Diagram describes the new process:



## 4.2 New Process

### 4.2.1 Outline

As shown in above Diagram, the new demand forecasting in 5MPD process operates as follows:

1. For the first interval of each 5MPD NEMDE Market Solver run, the 5MPD NEMDE Market Solver uses the forecast demand change produced by the EMS-based neural-network 5-Minute demand forecaster, as used by the Dispatch NEMDE Market Solver;
2. For the remaining eleven 5-minute intervals of each 5MPD NEMDE Market Solver run, the 5MPD NEMDE Market Solver uses the forecast demand changes provided to it by the 5MPD Solver Inputs Upload process, which shall now be based upon the historical average percentage demand change relevant to that interval, derived from the previous two weeks' of historical demand data.

The change from the previous 5MPD demand forecasting process is that the 5MPD process no longer uses Pre-dispatch demand forecasts. Rather, it applies forecast demand changes based upon the historical average percentage demand change relevant to that dispatch interval, based on the previous two weeks' worth of 5-minute demand data, to produce demand forecasts for all 5MPD intervals (other than the first interval) of every 5MPD run.

Separate average percentage demand change calculations are performed for weekday and weekend-type days where the 5MPD run schedule spans a weekday& weekend.

Note that there is no special public holiday treatment. This means that the 5MPD demand forecaster does not recognise whether an interval falls within a public holiday & simply treats that interval as any other day, being either a weekday or a weekend day.

It should also be noted that the 5MPD demand forecasting process is set up so that the forecast demand change for the Snowy1 NEM region is always set to zero, given that Snowy1 is a generation-only region.

### 4.2.2 Detail

The following describes in detail the new 5MPD demand forecasting process.

### 4.2.3 5MPD Average Percentage Demand Change calculation

For every 5MPD run the 5MPD Solver Inputs Uploader process dynamically calculates the 5-minute historical Average Percentage Demand Change for each 5-minute interval of the current 5MPD schedule. If the 5MPD run schedule extends between a weekday and a weekend day then the historical demand data used in the Average Percentage Demand Change calculation shall be taken from the last 2 weeks' of weekday data for the weekday-type 5MPD intervals and from the last 2 weeks' of weekend data for the weekend-type 5MPD intervals.

Note that for the purposes of determining day-type a day covers dispatch intervals ended 00:05 to 00:00 inclusive.



The Average Percentage Demand Change to be applied to the initial demand in each weekday (weekend day) 5MPD interval consists of the average of the Demand Changes calculated for that same 5-minute interval over all weekdays (weekend days) of the previous two weeks (not including the current day) expressed as a percentage of the average of the actual demands at the start of those historical 5-minute intervals.

In the case where historical demand data is unavailable or some dispatch interval solutions are missing, this averaging process is completed with data from the unavailable dispatch intervals excluded. This is unlikely to happen as the last Dispatch run solutions are automatically populated forward into missing dispatch interval runs, according to current MMS arrangements.

The 5-minute Average Percentage Demand Change for any dispatch interval ended  $k$  is then calculated as follows:

**5-minute Average Percentage Demand Change  $_k$  =**

$$\frac{\{ \text{Average over previous 2 weeks of [5-minute actual demand change] }_k \}}{\text{divided by}} \{ \text{Average over previous 2 weeks of [5-minute actual demand }_{(k-1)} \}$$

where;

**5-minute actual demand change** for dispatch interval ended  $k$  is the difference between the actual raw demands, as follows:

**5-minute actual demand change  $_k$  =**

$$\begin{aligned} & \text{5-minute actual demand }_k \\ & \text{minus} \\ & \text{5-minute actual demand }_{(k-1)} \end{aligned}$$

OR...

**5-minute actual demand change  $_k$  =**

$$\begin{aligned} & \text{DISPATCHREGIONSUM.INITIALSUPPLY }_{(k+1)} \\ & \text{minus} \\ & \text{DISPATCHREGIONSUM.INITIALSUPPLY }_k \end{aligned}$$

Note from above equation that:

- The average is over the weekdays or weekend days depending on whether the 5MPD interval falls into a weekday or weekend day.
- 5-minute Average Percentage Demand Change  $_k$  will be set as zero if the denominator is zero. This is to avoid the rare situation that the total demand denominator term is zero.

- 5-minute actual demand  $d_k =$   
DISPATCHREGIONSUM.INITIALSUPPLY<sub>(k+1)</sub>.

Refer to Appendix A for more details for the percentage demand change calculation.

There is a separate calculation performed for every NEM region, including the generation-only Snowy1 region.

#### 4.2.4 5MPD Forecast Demand & Demand Change calculations

The previous Section described how the 5MPD Solver Inputs Uploader process calculates the weekday & weekend Average Percentage Demand Changes for each interval of the current 5MPD run. This Section (& Steps 1 to 5 below) describes how those Average Percentage Demand Changes are translated into forecast demand changes.

The 5MPD Solver Inputs Uploader now determines for each of the twelve 5MPD intervals in turn the forecast demand change (aka the forecast demand offset) & the forecast demand, based on the Average Percentage Demand Change for each interval.

Each forecast demand change is firstly capped and floored to within pre-defined MW upper & lower limits defined for that particular NEM region before using this value to determine the forecast demand for the end of that interval. Once this processing is completed, all forecast demand changes (except for the first interval) are then passed to the 5MPD Solver.

For the first 5MPD interval only the forecast demand change determined by the 5MPD Solver Inputs Uploader is discarded & not passed to the 5MPD Solver, as the demand change forecast by the neural-network based 5-minute demand forecaster is used (as also used in 5-minute Dispatch).

Note that for the generation-only Snowy1 NEM region, the demand is typically near to zero MW as it only covers the Snowy pumping load plus interconnector losses which does not change over time. Given this the pre-defined upper & lower MW limits for the Snowy1 region are both set to zero, to ensure that only zero Average Percentage Demand Changes (that is, flat demand profile) are passed to the 5MPD Solver by the 5MPD Solver Inputs Uploader.

#### Step 1: Calculate Raw Forecast Demand Change & Forecast Demand

**Raw Forecast Demand Change**  $d_k$  (in MW)

= Initial Demand  $d_k$   
*multiplied by*  
Average Percentage Demand Change  $d_k$   
as calculated for that interval 'k' & relevant to that interval's day-type (weekday or weekend day)

**Raw Forecast Demand**  $d_k$  (in MW)

= Initial Demand  $d_k$   
*plus*

**Raw Forecast Demand Change  $k$** 

where;

**IF** *this is the first interval of the 5MPD run...*

**THEN**

**Initial Demand  $k$  = Forecast Demand  $_{(k-1)}$**   
 extracted from the previous Dispatch run 'k-1'

**ELSE IF** *this is the second or subsequent interval of the 5MPD run...*

**THEN**

**Initial Demand  $k$  = Raw Forecast Demand  $_{(k-1)}$**   
 as calculated by the 5MPD Solver Inputs Uploader for the  
 previous 5MPD interval 'k-1'

Note the Raw Forecast Demands are used at this Step to calculate the raw forecast changes only. They are not used in the latter Steps.

**Step 2: Apply Limits to Raw Forecast Demand Change**

**Forecast Demand Change  $k$**  (in MW)  
 = **Max { Lower Cap  $_r$  ,**  
**Min [ Upper Cap  $_r$  ,**  
**Raw Forecast Demand Change  $k$  ] }**

where;

Upper Cap  $_r$  = Maximum Demand Increase for NEM Region 'r'

Lower Cap  $_r$  = Maximum Demand Decrease for NEM Region 'r'

The initial Lower and Upper Cap values for the NEM regions are as follows:

REGION	LOWER CAP (MW)	UPPER CAP (MW)
SA1	-100	100
QLD1	-300	350
VIC1	-300	400
NSW1	-400	550
SNOWY1	0	0

### Step 3: Set zero Forecast Demand Change for first 5MPD interval

For the first 5MPD interval only, set the forecast demand change to zero MW before passing to the 5MPD Solver, as in the current 5MPD demand forecasting arrangement. This ensures that the 5MPD Solver calculates total forecast demand in the same way as the Dispatch Solver for the first 5MPD interval.

### Step 4: Pass all Forecast Demand Changes to 5MPD Solver

Forecast demand changes for all 5MPD intervals are then passed to the 5MPD Solver before triggering the 5MPD solver.

Ideally, the forecast demand changes calculated for the second interval should be based upon the forecast demand of the first 5MPD interval. However this cannot occur with the current design architecture, as the 5MPD Solver calculates the forecast demand for the first interval based upon the current metered demand and the demand change calculated by the neural network-based 5MDF, both of which are EMS database inputs that are not available until after the 5MPD Solver Inputs Uploader has completed passing its inputs to the 5MPD Solver.

As the forecast demand calculated by 5MPD Solver for the first 5MPD interval is unknown to the 5MPD Inputs Uploader beforehand then the 5MPD Solver Inputs Uploader must use the forecast demand from the latest run of the Dispatch process as a proxy when determining the forecast demand & forecast demand change profiles.

### Step 5: 5MPD Solver calculates Forecast Demands

After the 5MPD Solver has been triggered, it calculates the 5-minute Forecast Demands as follows:

**5-minute Forecast Demand  $_k$**

= **Initial Demand  $_k$**

*plus*

**Forecast Demand Change  $_k$**

where;

**IF** *this is the first interval of the 5MPD run...*

**THEN**

The above calculation is ignored and the 5MPD Solver calculates the forecast demand for the first interval based upon the current metered demand and the demand change calculated by the neural network-based Dispatch demand forecaster, as is done in the Dispatch process

**ELSE IF** *this is the second or subsequent interval of the 5MPD run...*

**THEN**

**Initial Demand  $_k$  = 5-minute Forecast Demand  $_{(k-1)}$**

as calculated by the 5MPD Solver for previous 5MPD interval 'k-1'

## Appendix A

The following example illustrates

- How the Average Percentage Demand Change is calculated for a particular interval; and
- How it is applied to produce demand forecasts in 5MPD process.

For this example, the forecast demand changes and total demands are produced for the 5MPD run 05/12/2003 23:50, following Steps specified in Sections 5.2.3 and 5.2.4. Note that this 5MPD run schedule covers both a weekday (Fri 05/12/2003) and a weekend day (Sat 06/12/2003).

**Firstly**, calculate the Average Percentage Demand Changes for all twelve intervals of the 5MPD schedule, using the following formula specified in Section 5.2.3:

**5-minute Average Percentage Demand Change  $_k$  =**

$$\frac{\{ \text{Average over previous 2 weeks of [5-minute actual demand change] }_k \}}{\text{divided by}} \{ \text{Average over previous 2 weeks of [5-minute actual demand] }_{(k-1)} \}$$

Note that the average is over all ten weekdays within the previous two weeks for the first three weekday type 5MPD intervals (05/12/2003 23:50 – 06/12/2003 00:00). For the remaining nine weekend type 5MPD intervals, the average is over the four weekend days within the previous two weeks. Here the previous two weeks' period refers to period 21/11/2003 00:05 – 5/12/2003 00:00 .

Assume that for each of the twelve 5MPD intervals, the 5-minute Average Percentage Demand Changes have been calculated using the above formula for NSW1 region as follows

**Table A1 – 5MPD Average Percentage Demand Change Calculation**

INTERVAL	INTERVAL TYPE	AVERAGE 5-MINUTE ACTUAL DEMAND CHANGE (MW)	AVERAGE 5-MINUTE ACTUAL DEMAND AT THE BEGINNING OF THE INTERVAL (MW)	5-MINUTE AVERAGE PERCENTAGE DEMAND CHANGE
23:50	Weekday	-27.76933877	7606.71	-0.003650637
23:55	Weekday	6.737795865	7613.55	0.000884974
0:00	Weekday	-22.32943842	7597.76	-0.00293895
0:05	Weekend day	4.296042635	7602.94	0.00056505
0:10	Weekend day	-52.92134636	7548.09	-0.007011224
0:15	Weekend day	-53.63456129	7493.44	-0.007157535
0:20	Weekend day	-95.6292139	7395.6	-0.012930555
0:25	Weekend day	-2.330971358	7393.64	-0.000315267
0:30	Weekend day	-43.40110923	7349.72	-0.005905138
0:35	Weekend day	-8.67027717	7341.42	-0.001181008
0:40	Weekend day	-56.18002748	7283.92	-0.007712884
0:45	Weekend day	-67.59036187	7215.78	-0.009367021

The last column in Table A1 is calculated using the 3<sup>rd</sup> and 4<sup>th</sup> column, which are derived from the historical 5-minute demand data for the concerned interval within the previous two weeks. This data is calculated similarly for other regions and it is used to derive the forecast demand changes.

**Secondly**, calculate the forecast demand changes and total demand, following steps specified in Section 5.2.4:

### **Step 1: Calculate Raw Forecast Demand Change and forecast total demand**

For simplicity, we only show this process for NSW1 region, using the data as shown in Table A1. For the purpose of this example, assume the total demand for the dispatch interval prior to current 5MPD run is **7900 MW**. Note this is the Dispatch forecast total demand for the interval ending 05/12/2003 23:45, which is used as the Initial total demand for the first 5MPD interval 05/12/2003 23:50.

As explained in Step 4, Section 5.2.4, ideally the metered total demand at the beginning of the interval 05/12/2003 23:50 should be used as the initial total demand. However this cannot occur with the current design architecture, as the metered total demand is calculated by 5MPD Solver, which happens after the 5MPD Uploader process (Steps 1-4) has been

completed. So, the 5MPD Solver Inputs Uploader must use the forecast demand from the latest run of the Dispatch process as a proxy when determining the forecast demand & forecast demand change profiles.

The following Table A2 illustrates how Step 1 is completed for the NSW1 region, using the formula specified in Section 5.2.4.

**Table A2. NSW1 Raw forecast demand change and total demand calculation.**

INTERVAL	5-MINUTE AVERAGE PERCENTAGE DEMAND CHANGE	INITIAL TOTAL DEMAND (MW)	RAW FORECAST DEMAND CHANGE (MW)	RAW FORECAST TOTAL DEMAND (MW)
05/12/2003 23:50	-0.003650637	7900	-28.84003417	<b>7871.159966</b>
05/12/2003 23:55	0.000884974	<b>7871.159966</b>	6.965774057	7878.12574
06/12/2003 0:00	-0.00293895	7878.12574	-23.15341937	7854.972321
06/12/2003 0:05	0.00056505	7854.972321	4.438453544	7859.410774
06/12/2003 0:10	-0.007011224	7859.410774	-55.1040859	7804.306688
06/12/2003 0:15	-0.007157535	7804.306688	-55.85960058	7748.447088
06/12/2003 0:20	-0.012930555	7748.447088	-100.1917226	7648.255365
06/12/2003 0:25	-0.000315267	7648.255365	-2.411243203	7645.844122
06/12/2003 0:30	-0.005905138	7645.844122	-45.14976297	7600.694359
06/12/2003 0:35	-0.001181008	7600.694359	-8.976482312	7591.717876

INTERVAL	5-MINUTE AVERAGE PERCENTAGE DEMAND CHANGE	INITIAL TOTAL DEMAND (MW)	RAW FORECAST DEMAND CHANGE (MW)	RAW FORECAST TOTAL DEMAND (MW)
06/12/2003 0:40	-0.007712884	7591.717876	-58.55403669	7533.16384
06/12/2003 0:45	-0.009367021	7533.16384	-70.56330293	7462.600537

For example, for the 5MPD interval 05/12/2003 23:50,

Initial Total Demand = 7900 MW (by assumption)

5-minute average percentage demand change = -0.003650637 (from Table A1)

Raw forecast demand change

$$= 5\text{-minute average percentage demand change} * \text{Initial Total Demand}$$

$$= 7900 \text{ MW} * (-0.003650637) = -28.84003417 \text{ MW.}$$

Raw forecast demand

$$= \text{Initial Total Demand} + \text{Raw forecast demand change}$$

$$= 7900 \text{ MW} + (-28.84003417) = 7871.159966 \text{ MW.}$$

The above-calculated raw forecast total demand is used as the initial total demand for the next interval 05/12/2003 23:55. The above process is then repeated to produce the forecast demand changes and total demands for the following 5MPD intervals.

## Step 2: Apply Limits to Raw Forecast Demand Change

The raw forecast demand changes are capped between the corresponding Lower and Upper Cap values for each region. For NSW1 region, it is clear that the raw forecast demand changes calculated in Table A2 are already between its Upper and Lower Cap values (-400 and 550 MW respectively), the capped forecast demand changes are then exactly the same as the raw forecast demand changes.



### Step 3: Set zero Forecast Demand Change for first 5MPD interval

For the first 5MPD interval only, set the forecast demand change to zero MW before passing to the 5MPD Solver, as in the current 5MPD demand forecasting arrangement.

This ensures that the 5MPD Solver calculates forecast total demand for the first 5MPD interval in the same way as the Dispatch Solver, where the forecast total demand is calculated as the sum of the metered total demand at the beginning of the interval and the forecast demand change produced by the neural-net based Dispatch 5-minute demand forecaster.

### Step 4: Pass all Forecast Demand Changes to 5MPD Solver

Forecast demand changes for all 5MPD intervals are then passed to the 5MPD Solver. These values are used in the Step 5 by the Solver to calculate the forecast total demands.

### Step 5: 5MPD Solver calculates Forecast Demands

This Step is illustrated using NSW1 region as an example. Assume that the total demand calculated by the 5MPD Solver for the first interval is **7200 MW**. It is used to produce the forecast total demands for the remaining eleven 5MPD intervals. The following Table A3 shows this process:

**Table A3: NSW1 forecast demand changes and total demands for 5MPD run 05/12/2003 23:50.**

INTERVAL	INITIAL TOTAL DEMAND	FORECAST DEMAND CHANGE (MW)	FORECAST TOTAL DEMAND (MW)
05/12/2003 23:50	Metered total demand at the beginning of the interval	Forecast produced by the Dispatch demand forecaster	<b>7200</b>
05/12/2003 23:55	<b>7200</b>	6.965774057	7206.965774
06/12/2003 0:00	7206.965774	-23.15341937	7183.812355
06/12/2003 0:05	7183.812355	4.438453544	7188.250808
06/12/2003 0:10	7188.250808	-55.1040859	7133.146722
06/12/2003 0:15	7133.146722	-55.85960058	7077.287122
06/12/2003	7077.287122	-100.1917226	6977.095399

INTERVAL	INITIAL TOTAL DEMAND	FORECAST DEMAND CHANGE (MW)	FORECAST TOTAL DEMAND (MW)
0:20			
06/12/2003 0:25	6977.095399	-2.411243203	6974.684156
06/12/2003 0:30	6974.684156	-45.14976297	6929.534393
06/12/2003 0:35	6929.534393	-8.976482312	6920.557911
06/12/2003 0:40	6920.557911	-58.55403669	6862.003874
06/12/2003 0:45	6862.003874	-70.56330293	6791.440571

In the above Table A3, the forecast total demand for the first 5MPD interval is used to calculate the forecast total demands for the following eleven intervals as follows

For the 5MPD interval 05/12/2003 23:55,

Initial total demand

= Forecast total demand of interval 05/12/2003 23:50

= 7200 MW (by assumption)

Forecast total demand

= Forecast demand change (Table A2 & Step 2) + Initial total demand

= 7200 + 6.965774057 = 7206.965774 MW.

The above-calculated forecast total demand is used as the initial total demand for the next interval 06/12/2003 00:00. The above process is then repeated to produce the forecast demand changes and total demands for the remaining 5MPD intervals.