Market Event Report

Constraint Action:

Moorabool Sydenham No 2 500kV Line Outage

11 September 2009

1.   Introduction

A constraint set applied to manage a short notice outage of the Moorabool–Sydenham no 2 500kV line on 11 September 2009 caused significant interconnector movements and large price variations in South Australia and Tasmania.

A constraint equation in this set is formulated assuming the simultaneous loss of both South Morang–Sydenham 500kV circuits as a single contingency. One of these circuits was however already out of service, i.e. prior to the outage of the Moorabool–Sydenham no 2 line. The constraint proved to be overly conservative given this prior outage, resulting in large changes in interconnector flows and energy prices reaching VoLL in South Australia.

2.   Summary of Events

2.1.   Description of Event

The South Morang-Sydenham no 2 500kV transmission line was out of service from 07:42hrs, 11 September 2009 on a planned outage. A problem with the remotely operated isolators prevented the return of the line to service with the Sydenham terminal station no 1 bus alive. The short notice outage of the Moorabool-Sydenham no 2 500kV line was required to close the remotely operated isolators manually. This outage commenced at 19:20hrs and ended at 19:35hrs.

Outage constraints were invoked and interconnector flows were ramped based on pre-dispatch outcomes. One of the constraint equations invoked to manage the short notice outage was too conservative and caused unexpected dispatch outcomes. The constraint equation was designed to protect the South Morang-Keilor 500kV line for the loss of both South Morang-Sydenham lines simultaneously. Since one of these lines was already out of service, the initial conditions were not suitable for the constraint equation. The constraint was blocked as soon as this was identified, i.e. 15 minutes after the constraint set was invoked.

2.2.   Pricing Outcomes: Energy and FCAS

Prices in South Australia reached $10,000/MWh at 19:25 and 19:30hrs. Negative prices of approximately -$1,000/MWh were recorded in Tasmania at 19:30 and 19:35hrs, as shown in Figure 1.
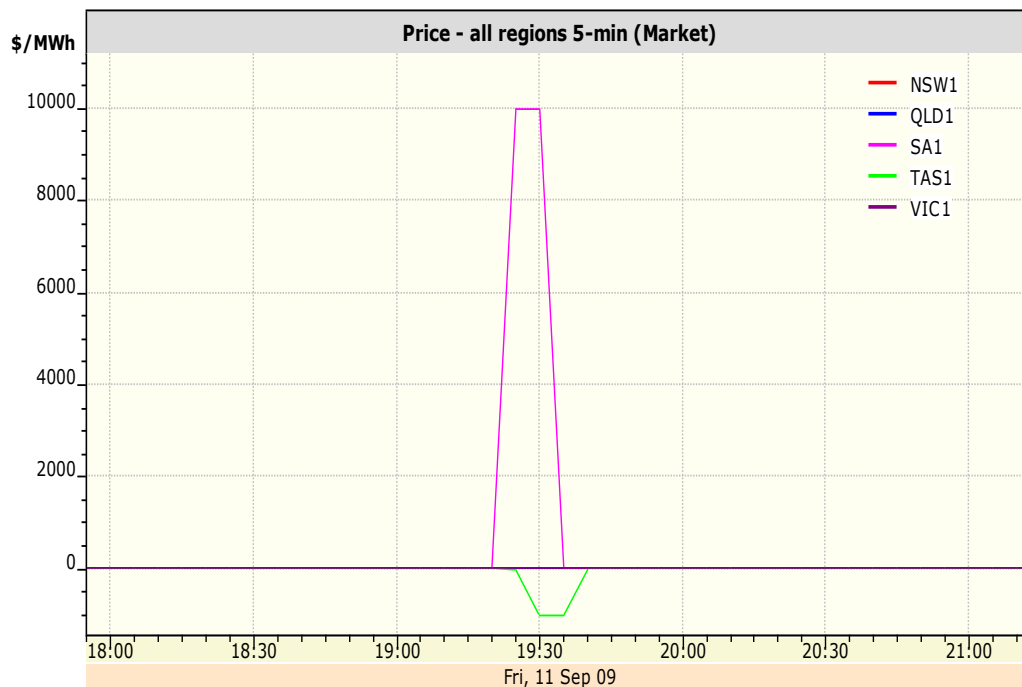

Figure 1   Dispatch Prices for All Regions

A price review event was triggered for South Australia at 19:25hrs. Although the newly-invoked outage constraint equations were suspect, the decision was that there was insufficient evidence to confirm that any of them was 'manifestly incorrect' and the prices were accepted.

The South Australia spot price was $3,347/MWh and the sum of the 4 Lower FCAS prices was $13,337/MW per hour for the trading interval ending 19:30hrs on Friday, 11 September 2009.

The Tasmanian spot prices were-$158/MWh and -$157/MWh for the trading intervals ending 19:30hrs and 20:00hrs and the sum of the 4 Lower FCAS prices was $810/MW per hour for the trading interval 20:00hrs.

Energy and FCAS prices for the other NEM regions were not affected.

2.3. Interconnector Flow

At 19:25hrs large changes in the interconnector flows occurred, as indicated in Figure 2.
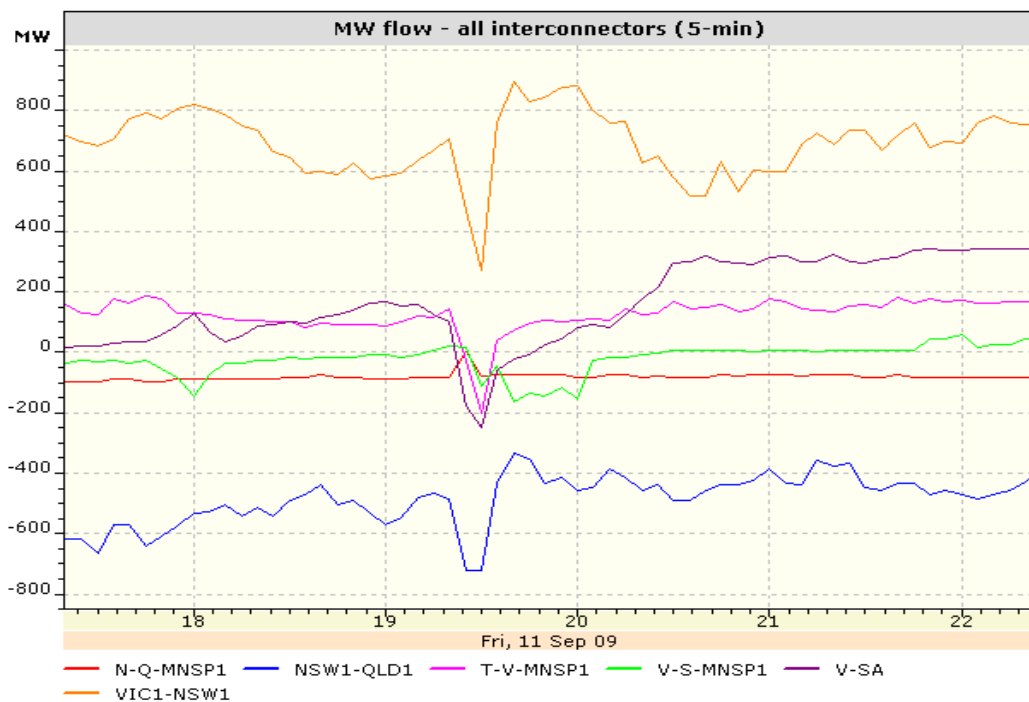

Figure 2   Changes in Interconnector Flow

Flow on the Basslink reversed towards Tasmania, and the flow on V-SA reversed towards Victoria. The flow from Queensland towards New South Wales on the NSW-QLD interconnector increased with almost 240MW, whilst the VIC-NSW interconnector flows towards New South Wales reduced by 260MW.

2.4. Constraint Application

The constraint set V-SMSY was invoked at 07:05hrs, 11 September 2009 to manage the planned South Morang-Sydenham no 2 500kV (SMTS-SYTS no 2) transmission line outage (refer to Figure 3).
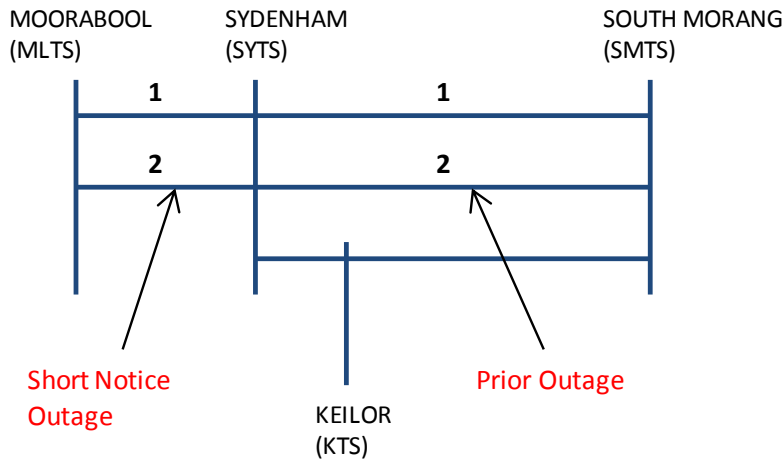

Figure 3   Single Line Diagram: Moorabool-Sydenham-South Morang

The constraints in this set assume the outage of one SMTS-SYTS line (in this case line 2). The constraints prevent the overload of the other SMTS-SYTS line (line 1) for the loss of the South Morang-Keilor 500kV line (SMTS-KTS). Conversely it also prevents the overload of the SMTS-KTS 500kV line for the loss of the SMTS-SYTS no 1 line.

At 18:36hrs a short notice outage of the Moorabool-Sydenham no 2 500kV line (MLTS-SYTS no 2) was requested to restore SMTS-SYTS no 2.

Permission to proceed (PTP) could not be given until the appropriate constraints had been invoked and a pre-dispatch run had occurred to determine the ramping target flows. The 30 minute pre-dispatch run executed at 19:00hrs for 19:30hrs indicated that the V-SA interconnector would bind in the Victoria to South Australia direction at 105MW, with the binding constraint being V>>V_SMSY_KTSM_1B (avoid overloading South Morang-Keilor for loss of South Morang-Sydenham no 1 line). No violating constraints were indicated in 30 minute pre-dispatch.

At 18:50hrs the 5-minute pre-dispatch schedule indicated high prices (refer to Figure 4).

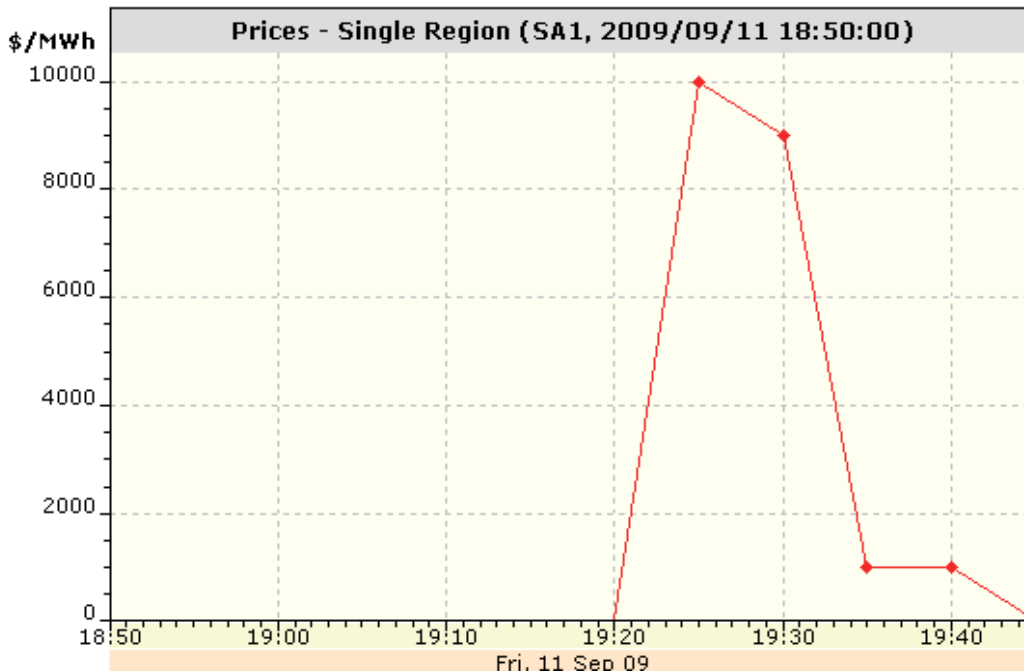Prices - Single Region (SA1, 2009/09/11 18:50:00)

Figure 4   Pre-Dispatch (5 minute) Prices: South Australia

In response a set of ramping constraints was invoked at 19:05hrs to ramp relevant plant and the VIC-SA interconnector down to an operating point where no high prices or constraint violations would occur. The ramping constraints did not bind during the period 19:05 to 19:25hrs (in dispatch as well as in 5 minute pre-dispatch). This was an indication that there would be no price shocks or large interconnector flow changes at the time of the outage.

It should be noted that high prices observed in 5 minute pre-dispatch often do not materialise in dispatch. Anomalies in forecast prices occur due to differences between current SCADA values, used as constant projections for the next hour, and actual values resulting from changed power system conditions.

Two constraint sets, V-MLSY and F-V-MLSY were invoked from 19:20hrs and the MLTS-SYTS no 2 line was taken out of service. Over-constrained dispatch occurred for the two dispatch intervals 19:25 and 19:30hrs due to the violation of one of the constraints in the set V-MLSY. The purpose of the constraint was to avoid overloading the SMTS-KTS line for the loss of SMTS-SYTS no 1, given that SMTS-SYTS no 2 is out of service. Two lower services FCAS constraints in the set F-V-MLSY were also violated. The violating constraint equation V>>V_MLSY2_1B was removed for the 19:35hrs dispatch interval, after contingency analysis confirmed that there were no security violations for the loss of the SMTS-SYTS no 1 line.

6

The action that was taken is in line with AEMO's dispatch procedures, as stated in operating guide SO_OP3705, Section 10:

"Constraints that are binding or violating and are identified as being overly conservative can unnecessarily constrain the market.

Overly conservative constraint equations can be removed from dispatch. This can be done by either blocking the constraint equation or removing it from the constraint set."

2.5.   **Reason for Constraint Violation**

The unexpected constraint violations occurred due to substantial differences in the RHS values in the Dispatch Schedule (DS) compared to the RHS values indicated in the Pre-dispatch Schedule (PDS). In the Pre-dispatch run performed at 19:00hrs for the 19:30hrs trading interval, the RHS value of the constraint was 2730MW. This value was significantly lower at 1237MW in the 19:30hrs Dispatch Schedule.

This DS and PDS difference can be attributed to the formulation of the MLTS-SYTS constraints. Due to the busbar arrangement at the Sydenham substation (SYTS), the loss of the SMTS-SYTS no 1 line with an outage of MLTS-SYTS no 2, results in the loss of both SMTS-SYTS 500kV lines. The constraint V>>V_MLSY2_1B was therefore formulated to keep the system secure for subsequent loss of **both** SMTS-SYTS 500 kV lines as a single credible contingency.

 A further contributing factor to the different DS and PDS values is the difference in the formulation of this constraint in the two schedules. The dispatch version of the constraint equation V>>V_MLSY2_1B uses a dynamic or *feedback constraint formulation* to calculate the headroom available on the protected South Morang-Keilor 500kV line for every 5 minute dispatch interval.

 The constraint measures the flow on one SMTS-SYTS line and assumes that 89.9% of the pre-contingency flow through each SMTS-SYTS line will transfer to the SMTS-KTS line during a contingency. This means the constraint uses the value (2*0.899 x SMTS-SYTS line no 1 flow) in its calculation of the headroom available on the SMTS-KTS 500kV line, as shown in the simplified version of the RHS of the constraint:

> SMTS-KTS 500kV 15min rating – MVA flow on SMTS-KTS - **1.778** x MVA flow on SMTS-SYTS 1 … *(+ generation and interconnector flow terms)* [1]

This formulation is correct as long as **both** of the SMTS-SYTS lines were in service. With one of the SMTS-SYTS lines already out of service, this approach was not correct since it significantly reduced

---

[1] Refer to the Appendix for the full formulation of the constraint V>>V_MLSY2_1B as applied on 11 September 2009.

the headroom available on the SMTS-KTS 500kV line, i.e. the RHS value was too conservative in dispatch.

The equivalent pre-dispatch constraint did not violate since it does not use the feedback formulation (and hence no SCADA values) in the RHS calculation.

3. Conclusion

A constraint was applied to manage the short notice outage of the Moorabool-Sydenham no 2 500kV line. A constraint in the set was designed for the simultaneous loss of both South Morang-Sydenham 500kV lines. One of these lines was already out of service when the constraint set was invoked, resulting in the initial conditions being inappropriate for the one of the constraints in the set.

The constraint proved to be too conservative and caused high energy and FCAS prices in South Australia as well as large changes in interconnector flows. The constraint was blocked as soon as the issue was identified, in accordance with AEMO's dispatch procedures.

The constraint set applied to manage this outage was subsequently revised by changing the constraints for a Moorabool-Sydenham line outage to take account of each of the South Morang – Sydenham 500kV no 1 and no 2 line flows individually.

4. Future Developments

AEMO's constraint management process was recently reviewed by KEMA, an international authority in energy consulting. As a result of this review AEMO is investigating the feasibility of developing an automated process that an operator can call upon quickly to evaluate the impact of a constraint set before invoking or revoking it.

Options will be examined carefully together with Market Systems to determine enhancements that would be justified on a cost vs benefit basis. It is planned for this review to be completed by mid 2010. Subsequent progress will depend upon the degree of changes required and the priority of the project.

Appendix: Formulation of V>>V_MLSY2_1B

Constraint: V>>V_MLSY2_1B
Constraint type: LHS<=RHS
Effective date: 24/06/2009
Constraint active in: Dispatch, Predispatch

Constraint description: Out = Sydenham - Moorabool No. 2 500kV line, avoid O/L the Keilor - South Morang 500kV line for trip of South Morang - Sydenham No. 1 500kV line. Yallourn unit 1 in 220kV mode, radial mode

Impact: Victorian Generation + Interconnectors

Limit type: Thermal

Reason: Avoid O/L the Keilor - South Morang 500kV line for trip of South Morang Sydenham No. 1 500kV line

LHS

0.08227 x Murray hydro (14 aggregated units)
-0.90915 x Anglesea
-0.763357 x Laverton North GT (2 aggregated units)
0.085062 x Hume (Vic) hydro
0.407105 x Hazelwood unit 1
0.407105 x Hazelwood unit 2
0.407105 x Hazelwood unit 3
0.407105 x Hazelwood unit 4
0.407105 x Hazelwood unit 5
0.407105 x Hazelwood unit 6
0.407105 x Hazelwood unit 7
0.407105 x Hazelwood unit 8
0.407105 x Jeeralang A GT unit 1
0.407105 x Jeeralang A GT unit 2
0.407105 x Jeeralang A GT unit 3
0.407105 x Jeeralang A GT unit 4
0.407105 x Jeeralang B GT unit 1
0.407105 x Jeeralang B GT unit 2
0.407105 x Jeeralang B GT unit 3
0.407104 x Loy Yang A unit 1
0.407104 x Loy Yang A unit 2

0.407104 x Loy Yang A unit 3
0.407104 x Loy Yang A unit 4
0.407104 x Loy Yang B unit 1
0.407104 x Loy Yang B unit 2
0.407104 x Valley Power GT (6 aggregated units)
0.407105 x Morwell unit 4
0.407105 x Morwell unit 5
0.407106 x Morwell (units 1, 2 & 3 aggregated)
0.40712 x Bairnsdale GT unit 1
0.40712 x Bairnsdale GT unit 2
-0.376067 x Newport GT
-0.087094 x Somerton GT (4 aggregated units)
0.133703 x Yallourn W unit 1
0.133703 x Yallourn W unit 2
0.133703 x Yallourn W unit 3
0.133703 x Yallourn W unit 4
0.407104 x MW flow north on the Basslink DC Interconnector
0.442375 x MW flow west on the Murraylink DC Interconnector
0.999983 x MW flow west on the Vic-SA AC interconnector

RHS

Default RHS value = 1100

Dispatch RHS =

1.70163 x **(** -1 x [MVA flow on South Morang to Keilor 500 kV line at South Morang, line end switched MVA]
- 1.77843 x [MVA flow on South Morang to Sydenham No. 1 500 kV line at South Morang, line end switched MVA][2]
+ Victoria: South Morang to Keilor 500kV 15min Rating

---

[2] The constraint has been revised to use individual flow measurements on SMTS-SYTS No.1 and No.2 lines:
Dispatch RHS=
1.70163 x **(** 0.95 x [Victoria: South Morang to Keilor 500kV 15min Rating]
- MVA flow on South Morang to Keilor 500 kV line at South Morang, line end switched MVA
- 0.89914 x [MVA flow on South Morang to Sydenham No. 1 500 kV line at South Morang, line end switched MVA]
- 0.89914 x [MVA flow on South Morang to Sydenham No. 2 500 kV line at South Morang, line end switched MVA])
+ ....

- 40 {Margin})
+ 0.407104 x [Loy Yang A unit 1]
+ 0.407104 x [Loy Yang A unit 3]
+ 0.407104 x [Loy Yang A unit 4]
+ 0.407104 x [Loy Yang A unit 2]
+ 0.407104 x [Loy Yang B unit 1]
+ 0.407104 x [Loy Yang B unit 2]
+ 0.133703 x [Yallourn W unit 2]
+ 0.133703 x [Yallourn W unit 3]
+ 0.133703 x [Yallourn W unit 4]
+ 0.407105 x [Hazelwood unit 1]
+ 0.407105 x [Hazelwood unit 2]
+ 0.407105 x [Hazelwood unit 3]
+ 0.407105 x [Hazelwood unit 4]
+ 0.407105 x [Hazelwood unit 5]
+ 0.407105 x [Hazelwood unit 6]
+ 0.407105 x [Hazelwood unit 7]
+ 0.407105 x [Hazelwood unit 8]
+ 0.407105 x [Jeeralang B GT unit 1]
+ 0.407105 x [Jeeralang B GT unit 2]
+ 0.407105 x [Jeeralang B GT unit 3]
+ 0.407105 x [Jeeralang A GT unit 1]
+ 0.407105 x [Jeeralang A GT unit 2]
+ 0.407105 x [Jeeralang A GT unit 3]
+ 0.407105 x [Jeeralang A GT unit 4]
- 0.376067 x [Newport GT]
+ 0.407105 x [Morwell unit 4]
+ 0.407105 x [Morwell unit 5]
- 0.90915 x [Anglesea]
+ 0.40712 x [Bairnsdale GT unit 1]
+ 0.40712 x [Bairnsdale GT unit 2]
+ 0.407104 x [MW flow north on the Basslink DC Interconnector]
+ 0.442375 x [MW flow west on the Murraylink DC Interconnector]
+ 0.133703 x [Yallourn W unit 1]
+ 10000 x [Yallourn unit 1 status (=1 in 500kV mode, =0 otherwise)]
+ 0.085062 x [Hume (Vic) hydro]
+ 0.999983 x [MW flow west on the Vic-SA AC interconnector]
+ 0.407106 x [Morwell (units 1, 2 & 3 aggregated)]
- 0.087094 x [Somerton GT (4 aggregated units)]
- 0.763357 x [Laverton North GT (2 aggregated units)]
+ 0.407104 x [Valley Power GT (6 aggregated units)]
+ 0.08227 x [Murray hydro (14 aggregated units)]

Predispatch RHS =

1.70163 x **(** -0.172995 x [Victoria region demand]
+ 39.398438 {PD_Const}
+ Victoria: South Morang to Keilor 500kV 15min Rating
- 40 {Margin}**)**
+ 0.055693 x [Eildon hydro unit 1]
+ 0.055693 x [Eildon hydro unit 2]
- 0.999857 x [Portland Wind Farm]
- 0.784541 x [Waubra Wind Farm]
+ 0.024577 x [Uranquinty GT unit 1]
+ 0.024577 x [Uranquinty GT unit 2]
+ 0.024577 x [Uranquinty GT unit 3]
+ 0.024577 x [Uranquinty GT unit 4]
+ 10000 x [Yallourn unit 1 status (=1 in 500kV mode, =0 otherwise)]
- 0.019179 x [Dartmouth hydro]
+ 0.011809 x [Blowering hydro (3 aggregated units)]
+ 0.074907 x [MW flow north on the Vic to NSW AC Interconnector]
- 0.019179 x [McKay Creek (units 1-6) plus Bogong hydro (units 1-2) aggregate]
- 0.019179 x [McKay hydro (units 2 & 4 aggregated) - deregistered - incorporated in MKAY1]
- 0.019179 x [West Kiewa hydro (units 1 & 2 aggregated)]
- 0.019179 x [West Kiewa hydro (units 3 & 4 aggregated)]
- 0.741415 x [Challicum Hills Wind Farm]
- 0.007363 x [Guthega hydro (2 aggregated units)]