# Power System Operating Incident Report – Trip of Heywood M1 500/275 kV Transformer on 1 Oct 2013

PREPARED BY:     AEMO System Capability

DATE:     17 January 2014

STATUS:     FINAL

## Contents

## Disclaimer

## Version Release History

| VERSION | DATE | BY | CHANGES | CHECKED BY | AUTHORISED BY |
|---------|------|-----|---------|------------|---------------|
| 1 | 17 Jan 2013 | S Darnell | FINAL | P Biddle | P Biddle |

## Incident Classifications

| | |
|---|---|
| Time and date and of incident | 0501 hrs Tuesday 1 October 2013 |
| Region of incident | Victoria |
| Affected regions | Victoria and South Australia |
| Event type | PSS – Power System not in a secure operating state longer that 30 min |
| Primary cause | TE- Transmission Equipment Failure |
| Impact | NS (Not Significant) |
| Associated reports | AEMO Electricity Pricing Event Report – Tuesday 1 October 2013 and Wednesday 2 October 2013 |

## Abbreviations

| Abbreviation | Term |
|--------------|------|
| AC | Alternating Current |
| AEMO | Australian Energy Market Operator |
| APD | Alcoa Portland |
| CB | Circuit Breaker |
| CVP | Constraint Violation Penalty |
| EMMS | Electricity Market Management System |
| EMS | Energy Management System |
| FCAS | Frequency Control Ancillary Services |
| FCAS L6 | Six second lower frequency control ancillary service |
| kV | Kilovolt |
| MW | Megawatt |
| NEMDE | National Electricity Market Dispatch Engine |
| NER | National Electricity Rules |
| SA | South Australia |

# 1  Introduction

This report reviews a power system operating incident that occurred on Tuesday 1 October 2013 in the Victorian region. The National Electricity Rules (NER) require AEMO to review this incident as the power system was in an insecure state for more than thirty minutes[1].

The purpose of this incident review is to assess power system security over the course of the incident. The NER requires AEMO to assess the adequacy of the provision and response of facilities and services and the appropriateness of actions taken to restore or maintain power system security[2].

This report is based upon information provided by AEMO[3] and SP AusNet[4]. Data from AEMO's Energy Management System (EMS) and Electricity Market Management System (EMMS) has also been used in analysing the incident.

References to time in this report are to National Electricity Market time (Australian Eastern Standard Time).

# 2  The Incident

On 1 October 2013 at 0501 hrs the Heywood M1 500/275 kV transformer tripped due to a cable fault. As a consequence, one of two transmission circuits that connect Victoria to South Australia via Heywood substation (VIC-SA interconnector circuit) was disconnected.

Following the loss of this interconnector circuit, AEMO invoked several constraint sets, as shown in Table 1, to manage power system security should the second interconnector circuit fail. These constraint sets manage voltage unbalance at Alcoa Portland (APD) substation, frequency control in SA and power system stability. See Appendix 1 for a list of constraint equations contained within the constraint sets.

**Table 1 – Constraint Sets Invoked by AEMO**

| Constraint Set | DI Invoked | Description |
|---|---|---|
| F-V-HY_TX | 0510 hrs | Out = one Heywood 500/275 (M1 or M2) transformer – FCAS requirements |
| V-HYTX | 0510 hrs | Out = one Heywood 500/275 (M) transformer |
| F-I-HYSE | 0515 hrs | Out = Heywood to South East 275 kV line – FCAS requirements |
| F-V-HYTR | 0515 hrs | Out = Heywood to Tarrone No1 500 kV line – FCAS requirements |
| I-HYSE | 0515 hrs | Out = Heywood to South East 275 kV line |
| V-HYTR | 0515 hrs | Out = Heywood to Tarrone No1 500 kV line |

One impact of invoking the constraint sets was that several constraints violated as shown in Figure 1. In particular two frequency control ancillary service constraints, F_S++HYML_L6[5] and F_S++HYSE_L6[6], violated for the eight dispatch periods, from Dispatch Interval (DI) ending 0520 hrs to DI ending 0555 hrs. The two constraints violated because there was insufficient FCAS Fast Lower (L6) services available in South Australia to meet dispatch requirements based on the VIC – SA interconnector flow at the time.

The determinant for investigating this incident is that two constraints violated for forty minutes following the trip of a transmission element. When a constraint violates the power system is likely to be in an

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[1] NER v60 Clause 4.8.15(a)(1)(iv) and AEMC Reliability Panel Guidelines for Identifying Reviewable Operating Incidents.
[2] NER v60 Clause 4.8.15 (b)
[3] In Victoria AEMO is both the National Electricity Market operator and the Victorian Transmission Network Service Provider.
[4] SP AusNet is the Transmission Network Service Provider in the Victoria region. Information provided by SP AusNet has been provided on a without prejudice basis and nothing in this report is intended to constitute, or may be taken by any person as constituting, an admission of fault, liability, wrongdoing, negligence, bad faith or the like on behalf of SP AusNet (or its respective associated companies, businesses, partners, directors, officers or employees).
[5] Out = one line between Heywood and Moorabool or one line Moorabool to Sydenham 500KV line – SA lower 6 sec requirement
[6] Out = one Heywood to South East or one Heywood 500/275KV (M1 or M2) transformer – SA lower 6 sec requirement

insecure state. That is, following a subsequent credible contingency the power system may be in an unsatisfactory state - in this case for the trip of the second VIC-SA interconnector circuit there would be insufficient FCAS L6 services to control frequency in South Australia.

Generally, AEMO is required to operate the power system in a secure state at all times, so in the event of a violating constraint AEMO is required to implement remedial action to relive the constraint.

**Figure 1 – Constraints that Violated Following AEMO Invoking Constraint Sets**
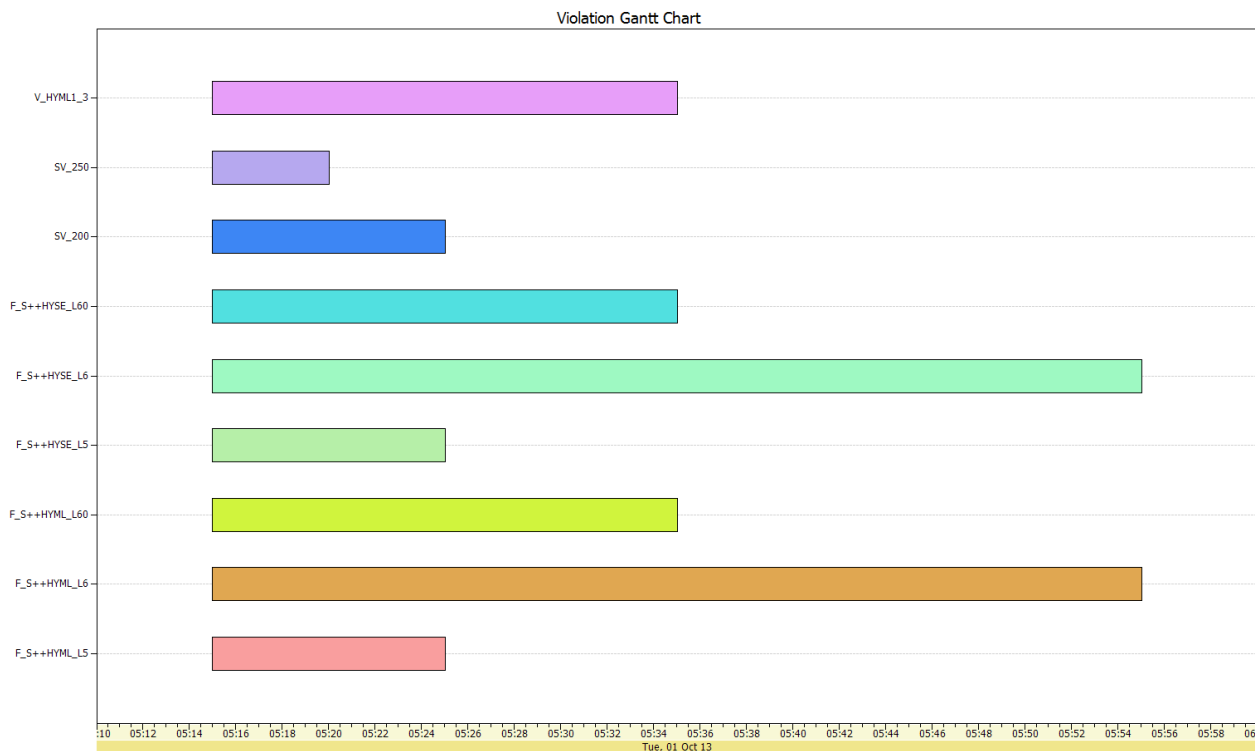


## 3   TNSP Investigation

SP AusNet investigated the trip of the Heywood M1 500/275 kV transformer and found the cause of the trip to be a damaged 22 kV cable connected to the tertiary winding of the transformer. The transformer restricted earth fault protection correctly detected and cleared the fault within the NER specified clearance times. SP AusNet removed the damaged cable and returned the transformer to service the following day.

## 4   AEMO Investigation

AEMO investigated the reason for the FCAS constraint equations violating for forty minutes. AEMO found that a binding higher priority voltage unbalance constraint, V_HYML1_4[7], to be the root cause of the FCAS constraint violations.

When the Heywood M1 transformer tripped AEMO invoked six constraint sets - see Table 1. For DI ending 0515 hrs constraint F_S++HYSE_L60[8] (part of sets F-V-HY_TX and F-I-HYSE) bound targeting a reduction in the flow from SA to VIC to match the FCAS L60 service available in SA. This was required to ensure that on

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[7] Out = Heywood to Tarrone or Tarrone to Moorabool No1 500KV line, limit voltage unbalance at the APD 500KV bus, one Mortlake unit in service.
[8] Out  = one Heywood to South East or Heywood (M1 or M2) transformer, SA lower 60 sec requirement

the loss of the remaining VIC-SA interconnector circuit the South Australian frequency would remain within the frequency standards.

For DI ending 0520 hrs a number of energy and FCAS constraints violated as shown in Figure 1. The majority of these violations were resolved within five dispatch intervals, however two L6 FCAS constraints, F_S++HYSE_L6 (part of constraint sets F-V-HY_TX and F-I-HYSE) and F_S++HYML_L6 (part of constraint set F-V-HYTR) continued to violate until DI 0555hrs (eight DIs, 40 minutes).

The reason for this is that constraint V_HYML1_4, with a Constraint Violation Penalty (CVP) of 360, invoked to manage voltage unbalance on the APD bus, required a large flow, initially 328MW, from South Australia to Victoria due to the level of Mortlake generation on line. The higher the level of Mortlake generation the higher the flow required from SA to VIC. At the same time the two FCAS constraints F_S++HYSL_L6 and F_S++HYML_L6 required a reduction in flow from SA to Vic but due to the lower CVP (6) were violated.

Over the period from DI 05:20 to DI 05:55 NEMDE targeted down the Mortlake generation and consequently the flow from SA to Vic. By DI 06:00 Mortlake generation was dispatched to zero MW and the flow from SA to Vic was reduced to a level to match the amount of L6 FCAS available in South Australia and constraints F_S++HYSE_L6 and F_S++HYML_L6 were no longer violating.

## 5    System Diagrams

The status of the power system before the incident is shown in Figure 2 and after the incident in Figure 3. For clarity only equipment relevant to this incident has been included in the diagrams. The diagrams show the Heywood M1 500/275 kV transformer in service in Figure 2 and out of service in Figure 3. Also in Figure 3 the Heywood – Tarrone 500 kV transmission line is out of service.

**Figure 2 - Status of the power system before the incident**
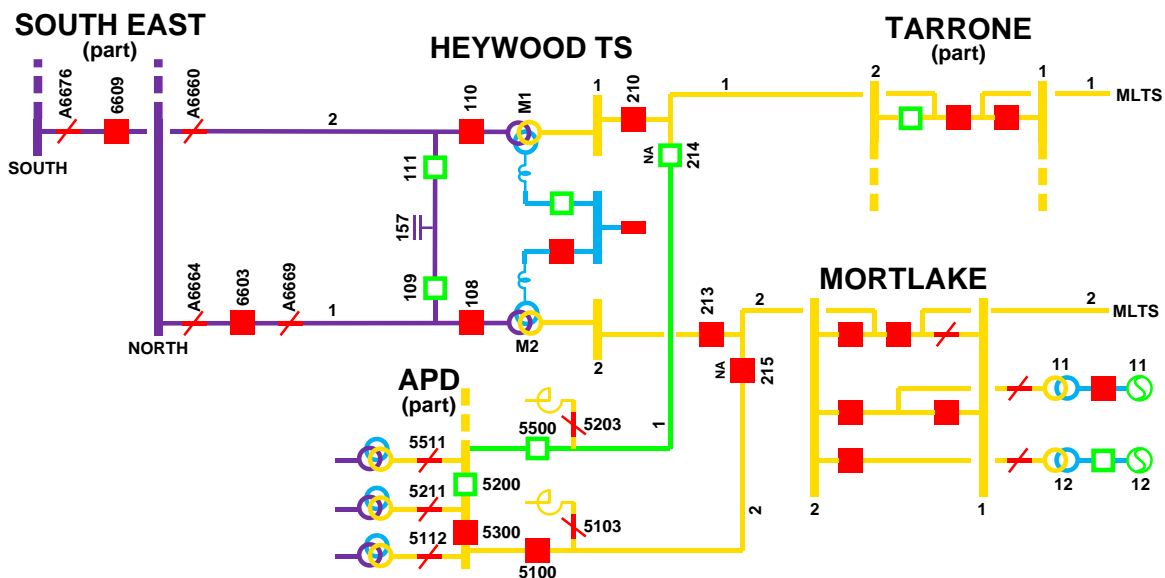
**Figure 3 - Status of the power system after the incident**
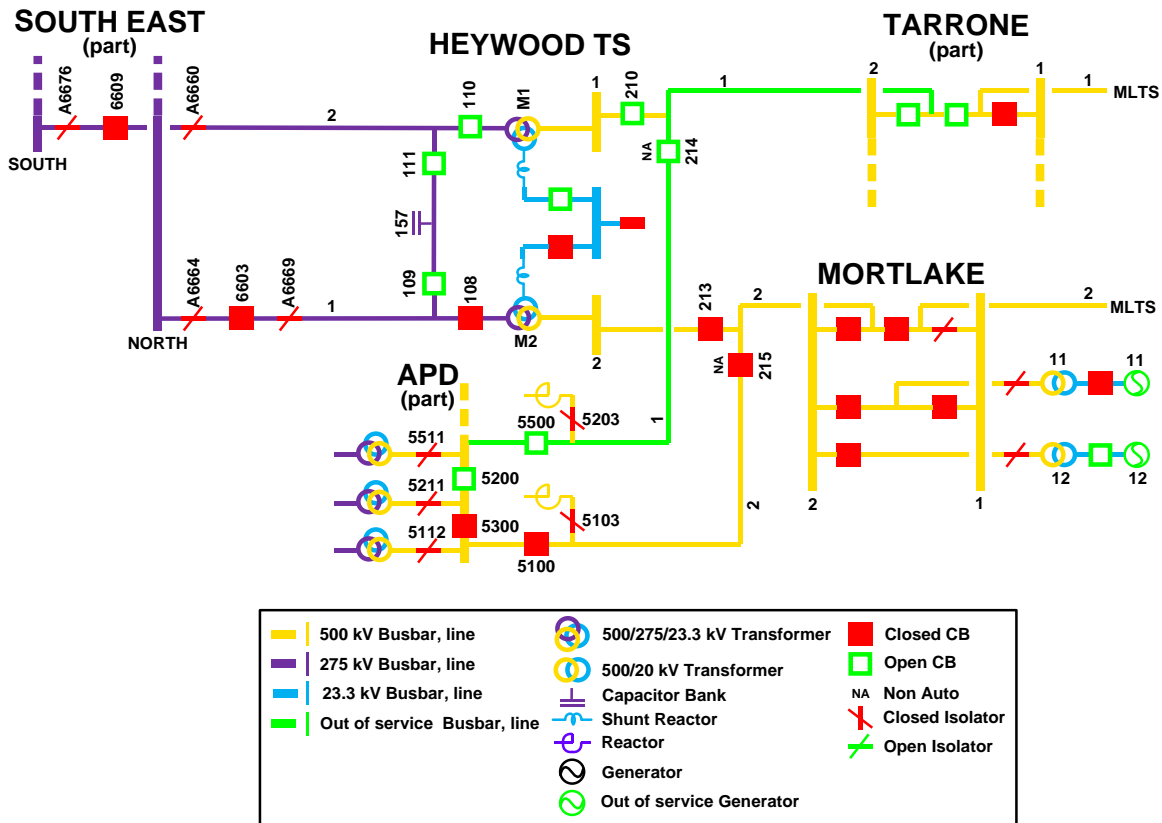


**Table 2 – Event Log**

| Time and Date | Event |
|---|---|
| 0730 hrs  23 Sept 2013 | Alcoa Portland – Heywood No.1 Transmission Line out of service for planned maintenance |
| 0501 hrs  1 Oct 2013 | M1 500/275 kV Transformer at Heywood Substation tripped |
| 0505 -0510 hrs  1 Oct 2013 | AEMO invoked Constraint sets:<br>• F-V-HY_TX, F-I-HYSE, F-V-HYTR, V-HYTX, V-HYTR, I-HYSE |
| 0507 hrs  1 Oct 2013 | Heywood – Tarrone No.1 500 kV Transmission Line de-energised for voltage control |
| 0515 hrs   1 Oct 2013 | Constraints equations F_S++HYML_L6, F_S++HYML_L6  violate<br>Constraint equation V_HYML1_4 binds |
| 0519 hrs  1 Oct 2013 | Market Notice 43483 issued: notification of the unplanned outage and that constraint sets have been invoked |
| 0555 hrs  1 Oct 2013 | Constraint equations F_S++HYSL_L6 and F_S++HYML_L6 cease to violate |
| 0600 hrs  1 Oct 2013 | Constraint equation V_HYML1_4 ceases to bind<br>Mortlake generation off-line |
| 0248 hrs  2 Oct 2013 | M1 Transformer at Heywood Substation returned to service |
| 1245 hrs  25 Oct 2013 | Alcoa Portland – Heywood No.1 Transmission Line returned to service |

# 6    Incident Event Log

The sequence of events comprising the incident are itemised in Table 2. FCAS constraints F_S++HYSL_L6 and F_S++HYML_L6 violated from 0515hrs to 0555 hrs.

# 7    Immediate Actions

This section assess the actions taken as the immediate response to the incident

AEMO invoked constraint sets F-V-HY_TX, F-I-HYSE, F-V-HYTR, V-HYTX, V-HYTR, I-HYSE to manage power system security whilst Heywood M1 500/275 kV transformer was out of service. The constraints were required to manage FCAS, voltage unbalance and transient instability.

SP AusNet de-energised the off-loaded Heywood – Tarrone 275 kV transmission line. This was to prevent high voltages at the Heywood end of the de-loaded Heywood – Tarrone 275 kV transmission line.

These actions were appropriate under the outage conditions.

# 8    Follow-up Actions

This section assesses the follow-up actions taken to resolve the incident.

AEMO monitored the violating constraints with a view to returning the power system to a secure state[9]. AEMO recognised that the primary issue was to reduce Mortlake generation and consequently the flow from South Australia to Victoria. AEMO observed that over each consecutive dispatch interval NEMDE continued to reduce Mortlake generation and that the violation degree of the violating constraints was also reducing. As such the expectation was that the constraints would cease violating and the power system return to a secure state within a reasonable timeframe. Consequently AEMO took no further action.

**Table 3 Violation Degree for Constraints F_S++HYSL_L6 and F_S++HYML_L6**

| DI Ending | Violation Degree |
|-----------|------------------|
| 0520 hrs  | -222.43          |
| 0525 hrs  | -128.98          |
| 0530 hrs  | -37.44           |
| 0535 hrs  | -32.05           |
| 0540 hrs  | -18.25           |
| 0545 hrs  | -8.9             |
| 0550 hrs  | -6.43            |
| 0555 hrs  | -10.81           |
| 0600 hrs  | 0                |

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[9] AEMO is required to return the power system to a secure state within thirty minutes following a contingency event (NER v60 Clause 4.2.6 (b)).

## 9   Power System Security

This section assesses how AEMO managed power system security over the course of the incident.[10]

For this incident the power system was insecure for forty minutes. This was due to two FCAS constraints that violated for eight dispatch periods. The resolution to the violating FCAS constraints was to reduce SA to VIC energy flow which in turn required Mortlake generation to reduce.

Once Mortlake generation had reduced generation the FCAS constraint violations ceased. No intervention was required by AEMO. The power system then returned to a secure state.

## 10   Conclusions

1.  This event was triggered by trip of Heywood M1 500/275 kV transformer which then required AEMO to invoke constraint equations to manage the resulting technical envelope.

2.  A number of constraints violated for a short period however two FCAS constraints violated for forty minutes due to the requirements of a higher priority voltage unbalance constraint.

3.  The violating FCAS constraints the were resolved by reducing the SA to VIC flow which, via a voltage unbalance constraint, required reducing generation at Mortlake Power Station.

## 11   Recommendations

There are no recommendations arising from this incident.

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[10] AEMO is responsible for power system security in the NEM and is required to operate the power system in a secure operating state (NER Clause 4.2.4 (a)). AEMO must thereby ensure that the power system is maintained in, or returned to, a secure operating state following a contingency event.

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## Appendix 1

| Constraint Sets and Equations Invoked by AEMO | |
|---|---|
| | |
| **Constraint Set F-V-HY_TX** | |
| Constraint | Description |
| F_ESTN++HYSE_L5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Eastern Lower 5 min Requirement |
| F_ESTN++HYSE_L6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Eastern Lower 6 sec Requirement |
| F_ESTN++HYSE_L60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Eastern Lower 60 sec Requirement |
| F_ESTN++HYSE_R5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Eastern Raise 5 min Requirement |
| F_ESTN++HYSE_R6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Eastern Raise 6 sec Requirement |
| F_ESTN++HYSE_R60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Eastern Raise 60 sec Requirement |
| F_QNV++HYSE_L5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Lower 5 min Requirement, Basslink able to transfer FCAS |
| F_QNV++HYSE_L6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Lower 6 sec Requirement, Basslink able to transfer FCAS |
| F_QNV++HYSE_L60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Lower 60 sec Requirement, Basslink able to transfer FCAS |
| F_QNV++HYSE_R5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Raise 5 min Requirement, Basslink able to transfer FCAS |
| F_QNV++HYSE_R6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Raise 6 sec Requirement, Basslink able to transfer FCAS |
| F_QNV++HYSE_R60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Raise 60 sec Requirement, Basslink able to transfer FCAS |
| F_QNV+HYSE_L5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Lower 5 min Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYSE_L6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Lower 6 sec Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYSE_L60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Lower 60 sec Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYSE_R5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Raise 5 min Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYSE_R6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Raise 6 sec Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYSE_R60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Raise 60 sec Requirement, Basslink unable to transfer FCAS |
| F_S++HYSE_L5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, SA Lower 5 min Requirement |
| F_S++HYSE_L6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, SA Lower 6 sec Requirement |
| F_S++HYSE_L60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, SA Lower 60 sec Requirement |
| | |
| **Constraint Set  V-HYTX** | |
| Constraint | Description |
| SV_250 | SA to Victoria on Heywood upper transfer limit of 250 MW |
| V>>S_HYML_1 | Out = One Heywood 500/275 kV txfmr in service only, prevent overload of the in service 500/275 kV Heywood transformer for loss of Northern Power Station Unit 1 |
| V>>S_HYML_2 | Out = One Heywood 500/275 kV txfmr in service only, prevent overload of the in service 500/275 kV Heywood transformer for loss of Northern Power Station Unit 2 |

| V>>S_HYML_3 | Out = One Heywood 500/275 kV txfmr in service only, prevent overload of the in service 500/275 kV Heywood transformer for loss of Lake Bonney Wind Farm |
|---|---|
| V>>S_HYML_4 | Out = One Heywood 500/275 kV txfmr in service only, prevent overload of the in service 500/275 kV Heywood transformer for loss of a Pelican Point GT and consequent offloading of Pelican Point ST |
| VS_250 | Victoria to SA on Heywood upper transfer limit of 250 MW |
| | |

| Constraint Set  F-I-HYSE | |
|---|---|
| Constraint | Description |
| F_ESTN++HYSE_L5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Eastern Lower 5 min Requirement |
| F_ESTN++HYSE_L6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Eastern Lower 6 sec Requirement |
| F_ESTN++HYSE_L60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Eastern Lower 60 sec Requirement |
| F_ESTN++HYSE_R5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Eastern Raise 5 min Requirement |
| F_ESTN++HYSE_R6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Eastern Raise 6 sec Requirement |
| F_ESTN++HYSE_R60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Eastern Raise 60 sec Requirement |
| F_QNV++HYSE_L5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Lower 5 min Requirement, Basslink able to transfer FCAS |
| F_QNV++HYSE_L6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Lower 6 sec Requirement, Basslink able to transfer FCAS |
| F_QNV++HYSE_L60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Lower 60 sec Requirement, Basslink able to transfer FCAS |
| F_QNV++HYSE_R5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Raise 5 min Requirement, Basslink able to transfer FCAS |
| F_QNV++HYSE_R6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Raise 6 sec Requirement, Basslink able to transfer FCAS |
| F_QNV++HYSE_R60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Raise 60 sec Requirement, Basslink able to transfer FCAS |
| F_QNV+HYSE_L5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Lower 5 min Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYSE_L6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Lower 6 sec Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYSE_L60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Lower 60 sec Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYSE_R5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Raise 5 min Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYSE_R6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Raise 6 sec Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYSE_R60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, Qld, NSW, Snowy and Vic Raise 60 sec Requirement, Basslink unable to transfer FCAS |
| F_S++HYSE_L5 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, SA Lower 5 min Requirement |
| F_S++HYSE_L6 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, SA Lower 6 sec Requirement |
| F_S++HYSE_L60 | Out = one Heywood to South East (HYTS-SESS) or one Heywood (HYTS) 500/275kV (M1 or M2) transformer, SA Lower 60 sec Requirement |
| | |

| Constraint Set  F-V-HYTR | |
|---|---|
| Constraint | Description |
| F_ESTN++HYTR_L5 | Out = Heywood to Tarrone (HYTS-TRTS) line Eastern Lower 5 min Requirement |
| F_ESTN++HYTR_L6 | Out = Heywood to Tarrone (HYTS-TRTS) line, Eastern Lower 6 sec Requirement |
| F_ESTN++HYTR_L60 | Out = Heywood to Tarrone (HYTS-TRTS) line, Eastern Lower 60 sec Requirement |

| | |
|---|---|
| F_ESTN++HYTR_R5 | Out = Heywood to Tarrone (HYTS-TRTS) line, Eastern Raise 5 min Requirement |
| F_ESTN++HYTR_R6 | Out = Heywood to Tarrone (HYTS-TRTS) line, Eastern Raise 6 sec Requirement |
| F_ESTN++HYTR_R60 | Out = Heywood to Tarrone (HYTS-TRTS) line, Eastern Raise 60 sec Requirement |
| F_ESTN+MC_TG_R5 | Out= Moorabool to Tarrone or Heywood to Tarrone line, Eastern Raise 5 min requirement for Macarthur Generation loss on trip of other line |
| F_ESTN+MC_TG_R6 | Out= Moorabool to Tarrone or Heywood to Tarrone line, Eastern Raise 6 sec requirement for Macarthur Generation loss on trip of other line |
| F_ESTN+MC_TG_R60 | Out= Moorabool to Tarrone or Heywood to Tarrone line, Eastern Raise 60 sec requirement for Macarthur Generation loss on trip of other line |
| F_QNV++HYTR_L5 | Out = Heywood to Tarrone (HYTS-TRTS) line, Qld, NSW and Vic Lower 5 min Requirement, Basslink able to transfer FCAS |
| F_QNV++HYTR_L6 | Out = Heywood to Tarrone (HYTS-TRTS) line, Qld, NSW and Vic Lower 6 sec Requirement, Basslink able to transfer FCAS |
| F_QNV++HYTR_L60 | Out = Heywood to Tarrone (HYTS-TRTS) line, Qld, NSW and Vic Lower 60 sec Requirement, Basslink able to transfer FCAS |
| F_QNV++HYTR_R5 | Out = Heywood to Tarrone (HYTS-TRTS) line, Qld, NSW and Vic Raise 5 min Requirement, Basslink able to transfer FCAS |
| F_QNV++HYTR_R6 | Out = Heywood to Tarrone (HYTS-TRTS) line, Qld, NSW and Vic Raise 6 sec Requirement, Basslink able to transfer FCAS |
| F_QNV++HYTR_R60 | Out = Heywood to Tarrone (HYTS-TRTS) line, Qld, NSW and Vic Raise 60 sec Requirement, Basslink able to transfer FCAS |
| F_QNV++MC_TG_R5 | Out= Moorabool to Tarrone or Heywood to Tarrone line, Eastern Raise 5 min requirement for Macarthur Generation loss on trip of other line, Basslink able to transfer FCAS |
| F_QNV++MC_TG_R6 | Out= Moorabool to Tarrone or Heywood to Tarrone line, Eastern Raise 6 sec requirement for Macarthur Generation loss on trip of other line, Basslink able to transfer FCAS |
| F_QNV++MC_TG_R60 | Out= Moorabool to Tarrone or Heywood to Tarrone line, Eastern Raise 60 sec requirement for Macarthur Generation loss on trip of other line, Basslink able to transfer FCAS |
| F_QNV+HYTR_L5 | Out = Heywood to Tarrone (HYTS-TRTS) line, Qld, NSW and Vic Lower 5 min Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYTR_L6 | Out = Heywood to Tarrone (HYTS-TRTS) line, Qld, NSW and Vic Lower 6 sec Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYTR_L60 | Out = Heywood to Tarrone (HYTS-TRTS) line, Qld, NSW and Vic Lower 60 sec Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYTR_R5 | Out = Heywood to Tarrone (HYTS-TRTS) line, Qld, NSW and Vic Raise 5 min Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYTR_R6 | Out = Heywood to Tarrone (HYTS-TRTS) line, Qld, NSW and Vic Raise 6 sec Requirement, Basslink unable to transfer FCAS |
| F_QNV+HYTR_R60 | Out = Heywood to Tarrone (HYTS-TRTS) line, Qld, NSW and Vic Raise 60 sec Requirement, Basslink unable to transfer FCAS |
| F_QNV+MC_TG_R5 | Out= Moorabool to Tarrone or Heywood to Tarrone line, Eastern Raise 5 min requirement for Macarthur Generation loss on trip of other line, Basslink unable to transfer FCAS |
| F_QNV+MC_TG_R6 | Out= Moorabool to Tarrone or Heywood to Tarrone line, Eastern Raise 6 sec requirement for Macarthur Generation loss on trip of other line, Basslink unable to transfer FCAS |
| F_QNV+MC_TG_R60 | Out= Moorabool to Tarrone or Heywood to Tarrone line, Eastern Raise 60 sec requirement for Macarthur Generation loss on trip of other line, Basslink unable to transfer FCAS |
| F_S++HYML_L5 | Out = one line between Heywood and Moorabool (HYTS-MLTS)  or one Moorabool to Sydenham (MLTS-SYTS) 500kV line, SA Lower 5 min Requirement |
| F_S++HYML_L6 | Out = one line between Heywood and Moorabool (HYTS-MLTS)  or one Moorabool to Sydenham (MLTS-SYTS) 500kV line, SA Lower 6 sec Requirement |
| F_S++HYML_L60 | Out = one line between Heywood and Moorabool (HYTS-MLTS)  or one Moorabool to Sydenham (MLTS-SYTS) 500kV line, SA Lower 60 sec Requirement |
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| Constraint Set  I-HYSE | |
|---|---|
| Constraint | Description |
| Q:N_1078 | QNI oscillatory stability limit of 1078 MW |
| SV_200 | SA to Victoria on VicSA upper transfer limit of 200 MW |
| V::N_HYSEQA_R | Out = Heywood to South East 275kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink TAS to VIC, QLD accelerates, segment 1 |

| V::N_HYSEQB_R | Out = Heywood to South East 275kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink TAS to VIC, QLD accelerates, segment 2 |
|---|---|
| V::N_HYSEQC_R | Out = Heywood to South East 275kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink TAS to VIC, QLD accelerates, segment 3 |
| V::N_HYSEQD_R | Out = Heywood to South East 275kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink VIC to TAS, QLD accelerates, segment 1 |
| V::N_HYSEQE_R | Out = Heywood to South East 275kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink VIC to TAS, QLD accelerates, segment 2 |
| V::N_HYSEQF_R | Out = Heywood to South East 275kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink VIC to TAS, QLD accelerates, segment 3 |
| V::N_HYSEVA_R | Out = Heywood to South East 275kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink TAS to VIC, VIC accelerates, segment 1 |
| V::N_HYSEVB_R | Out = Heywood to South East 275kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink TAS to VIC, VIC accelerates, segment 2 |
| V::N_HYSEVC_R | Out = Heywood to South East 275kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink TAS to VIC, VIC accelerates, segment 3 |
| V::N_HYSEVD_R | Out = Heywood to South East 275kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink VIC to TAS, VIC accelerates, segment 1 |
| V::N_HYSEVE_R | Out = Heywood to South East 275kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink VIC to TAS, VIC accelerates, segment 2 |
| V::N_HYSEVF_R | Out = Heywood to South East 275kV line, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink VIC to TAS, VIC accelerates, segment 3 |
| V::S_HYSE | Out = One South East - Heywood 275 kV line; Vic to SA Stability limit for loss of one NPS unit or South East-Tailem Bend 275 kV line. |
| VS_250 | Victoria to SA on Heywood upper transfer limit of 250 MW |
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| **Constraint Set  V-HYTR** |  |
| Constraint | Description |
| Q:N_1078 | QNI oscillatory stability limit of 1078 MW |
| SV_250 | SA to Victoria on Heywood upper transfer limit of 250 MW |
| V::N_HYMLQA_R | Out = one 500 kV line between Heywood and Moorabool, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink TAS to VIC, QLD accelerates, segment 1 |
| V::N_HYMLQB_R | Out = one 500 kV line between Heywood and Moorabool, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink TAS to VIC, QLD accelerates, segment 2 |
| V::N_HYMLQC_R | Out = one 500 kV line between Heywood and Moorabool, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink TAS to VIC, QLD accelerates, segment 3 |
| V::N_HYMLQD_R | Out = one 500 kV line between Heywood and Moorabool, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink VIC to TAS, QLD accelerates, segment 1 |
| V::N_HYMLQE_R | Out = one 500 kV line between Heywood and Moorabool, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink VIC to TAS, QLD accelerates, segment 2 |
| V::N_HYMLQF_R | Out = one 500 kV line between Heywood and Moorabool, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink VIC to TAS, QLD accelerates, segment 3 |
| V::N_HYMLVA_R | Out = one 500 kV line between Heywood and Moorabool, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink TAS to VIC, VIC accelerates, segment 1 |
| V::N_HYMLVB_R | Out = one 500 kV line between Heywood and Moorabool, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink TAS to VIC, VIC accelerates, segment 2 |
| V::N_HYMLVC_R | Out = one 500 kV line between Heywood and Moorabool, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink TAS to VIC, VIC accelerates, segment 3 |
| V::N_HYMLVD_R | Out = one 500 kV line between Heywood and Moorabool, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink VIC to TAS, VIC accelerates, segment 1 |
| V::N_HYMLVE_R | Out = one 500 kV line between Heywood and Moorabool, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink VIC to TAS, VIC accelerates, segment 2 |
| V::N_HYMLVF_R | Out = one 500 kV line between Heywood and Moorabool, avoid transient instability for fault and trip of a Hazelwood to South Morang 500kV line, Basslink VIC to TAS, VIC accelerates, segment 3 |
| V>>S_HYML_1 | Out = One Heywood 500/275 kV txfmr in service only, prevent overload of the in service 500/275 kV Heywood transformer for loss of Northern Power Station Unit 1 |

| V>>S_HYML_2 | Out = One Heywood 500/275 kV txfmr in service only, prevent overload of the in service 500/275 kV Heywood transformer for loss of Northern Power Station Unit 2 |
|---|---|
| V>>S_HYML_3 | Out = One Heywood 500/275 kV txfmr in service only, prevent overload of the in service 500/275 kV Heywood transformer for loss of Lake Bonney Wind Farm |
| V>>S_HYML_4 | Out = One Heywood 500/275 kV txfmr in service only, prevent overload of the in service 500/275 kV Heywood transformer for loss of a Pelican Point GT and consequent offloading of Pelican Point ST |
| VS_250 | Victoria to SA on Heywood upper transfer limit of 250 MW |
| V_HYML1_1 | Out = Heywood to Tarrone, or Tarrone to Moorabool No. 1 500 kV line, limit voltage unbalance at the APD 500 kV bus, one Mortlake unit in service |
| V_HYML1_2 | Out = Heywood to Tarrone, or Tarrone to Moorabool No. 1 500 kV line, limit voltage unbalance at the APD 500 kV bus, one Mortlake unit in service |
| V_HYML1_3 | Out = Heywood to Tarrone, or Tarrone to Moorabool No. 1 500 kV line, limit voltage unbalance at the APD 500 kV bus, one Mortlake unit in service |
| V_HYML1_4 | Out = Heywood to Tarrone, or Tarrone to Moorabool No. 1 500 kV line, limit voltage unbalance at the APD 500 kV bus, one Mortlake unit in service |
| V_HYML1_5 | Out = Heywood to Tarrone, or Tarrone to Moorabool No. 1 500 kV line, limit voltage unbalance at the APD 500 kV bus, two Mortlake units in service |