Review of High Spring Washer Resolution Issue with SFT

Market Performance Review

7 October 2011

Investigation stages

An in-depth investigation will typically be the final step of a sequence of escalating investigation stages. The investigations are targeted at gathering sufficient information to decide whether a Code amendment or market facilitation measure should be considered.

Market Performance Enquiry (Stage I): At the first stage, routine monitoring results in the identification of circumstances that require follow-up. This stage may entail the design of low-cost ad hoc analysis, using existing data and resources, to better characterise and understand what has been observed. The Authority would not usually announce it is carrying out this work.

This stage may result in no further action being taken if the enquiry is unlikely to have any implications for the competitive, reliable and efficient operation of the electricity industry. In this case, the Authority publishes its enquiry only if the matter is likely to be of interest to industry participants.

Market Performance Review (Stage II): A second stage of investigation occurs if there is insufficient information available to understand the issue and it could be significant for the competitive, reliable or efficient operation of the electricity industry. Relatively informal requests for information are made to relevant service providers and industry participants. There is typically a period of iterative information-gathering and analysis. The Authority would usually publish the results of these reviews but would not announce it is undertaking this work unless a high level of stakeholder or media interest was evident.

Market Performance Formal Investigation (Stage III): The Authority may exercise statutory information-gathering powers under section 46 of the Act to acquire the information it needs to fully investigate an issue. The Authority would generally announce early in the process that it is undertaking the investigation and indicate when it expects to complete the work. Draft reports will go to the Board of the Authority for publication approval.

The outcome of any of the three stages of investigation can be either a recommendation for a Code amendment, provision of information to a Code amendment process already underway, a brief report provided to industry as a market facilitation measure, or a no further action.

From the point of view of participants, repeated information requests are generally concerned with Stage II; trying to understand the issue to such an extent that a decision can be made about materiality.

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Executive summary

A high spring washer (HSW) price situation occurs in a trading period when one or more transmission security constraint binds and the price at any connected grid injection point (GIP) or grid exit point (GXP) is equal to, or higher than, five times the highest unconstrained cleared offer price in that trading period.

When a HSW price situation occurs, a HSW price relaxation factor is applied. This is calculated as the greater of 1 MW or 1% of the constraint limit of the relevant binding transmission security constraint. The application of a HSW price relaxation factor is intended to remove spurious economic signals arising from the imprecision of model parameters and data used to calculate final prices. The relaxation process reduces the gap between the highest price and the highest unconstrained cleared offer price in the trading period.

Prior to the introduction of the simultaneous feasibility test (SFT) in March 2011, security constraints were applied manually. In a situation where two or more parallel transmission lines with very similar but not necessarily identical characteristics (such as capacity or impedance) are connected to the same substation bus, only one constraint was applied to protect the lines from being overloaded for a contingency of a grid component.

Since the introduction of SFT, one constraint is applied only if all the parallel lines have exactly the same characteristics. However, in reality, there are frequently very slight differences between parallel lines. As a result, SFT will apply one constraint to each of these parallel lines. If one of these constraints becomes binding and causes a HSW price situation, the constraint(s) on other parallel line(s) will also be very close to binding. This is because the constraints applied are only slightly different.

If the constraints applied to parallel lines are only fractionally different when a HSW price relaxation factor is applied to the binding constraint, this constraint will be relaxed but the next similar constraint could then become binding. As a result, the HSW price situation might not significantly change and the HSW price relaxation process will not have the intended effect.

This issue can occur whenever there are multiple constraints applied to similar, but not identical, parallel transmission lines and one of these constraints becomes binding causing a HSW price situation.

The Authority is working with the system operator to find a solution for this issue. The system operator is now investigating the scope of this issue.

1 Introduction

1.1 A HSW price situation is defined in Part 1 of the Electricity Industry Participation Code 2010 (Code). According to the Code a HSW price situation occurs in a trading period when one or more transmission security constraints bind, and the software used by the pricing manager to calculate provisional prices, interim prices, and final prices calculates a price for electricity at any grid injection point or grid exit point, excluding grid injection points and grid exit points that are disconnected, that is equal to or greater than the product of the high spring washer price trigger ratio and the highest unconstrained cleared offer price in that trading period.

1.2 In a HSW situation, the combined effect of the binding transmission constraint and the laws of electricity flow in a network, can mean that many MWs of expensive generation need to be dispatched to serve one more MW of load. This leads to a price amplification that is very sensitive to approximately known network electrical parameters. Although correct in a mathematical sense, extreme amplification of the highest cleared offer price is likely to provide spurious economic signals due to the imprecision of approximately known electrical parameters in the Scheduling, Pricing and Dispatch (SPD) model. Hence the use of a HSW price relaxation factor to reduce inefficient price volatility.

1.3 When a HSW price situation occurs, a HSW price relaxation factor is applied to the relevant transmission security constraint that has bound in the trading period. The HSW price relaxation factor is the greater of 1 MW or 1% of the constraint limit. Its application is intended to reduce the gap between the highest price and the highest unconstrained cleared offer price in that trading period.

1.4 As part of its update to the market systems software, Transpower introduced a software package to automatically calculate and apply security constraints in SPD. The new automated constraint builder is called the Simultaneous Feasibility Test (SFT).

1.5 Prior to the introduction of SFT, transmission constraints were applied manually. In a situation where two or more parallel transmission lines with the same or very similar characteristics (capacity, impedance, thermal rating) were connected to the same substation bus, only one constraint was applied to the parallel lines to protect them from being overloaded for a contingency of a grid component.

1.6 Since the introduction of SFT, one constraint is applied to each of the parallel lines, unless they have identical characteristics. In reality, there are frequently very slight differences between parallel lines. Consequently, each parallel line is given a fractionally different constraint. Should one of these constraints become binding, leading to a HSW price situation, the constraints on the other parallel line(s) will also become very close to binding.

1.7 If the constraints on parallel lines are only fractionally different, a HSW price relaxation factor applied to a binding constraint might only cause the next one to bind. As a result, the HSW price situation will not materially change and the HSW price relaxation process will not have the intended effect.

1.8 This report briefly summarises an underlying HSW price issue with SFT, and the current progress of solving the issue.

2 High spring washer price situation on 14 August 2011

2.1 On Sunday 14 August 2011, a HSW price situation occurred during trading period 35, on a constraint on one of the two parallel lines between Bunnythorpe and Woodville.

2.2 Data from the wholesale information and trading system (WITS) website shows that two similar constraints were applied to the two parallel lines between Bunnythorpe and Woodville. One of these constraints was binding and caused a HSW price situation in the Wellington and Bunnythorpe regions. This caused the price at Woodville to rise to $8,380/MWh, the price at Haywards to rise to $657/MWh and the price at Mangahao to fall to -$462/MWh.

2.3 A HSW price relaxation factor was applied to the binding constraint. However, the prices remained largely unaffected because the constraint on the other parallel line between Bunnyhtorpe and Woodville then bound.

2.4 Table 1 presents the values of the two constraints before and after the HSW price relaxation factor was applied. In this case, the two constraints are essentially the same. However, because there is a slight difference in the susceptance values between Bunnythorpe - Woodville circuits 1 and 2 (-11.01796 vs. -11.01671), the values of these two constraints were just slightly different (73.86 vs. 73.859). According to the current HSW price situation methodology specified in clause 13.134(2) of the Code, only the first constraint, the binding constraint, is to be relaxed. As a result, the HSW relaxation procedure had no marked effect on final prices.

Table 1 Constraint values in provisional and final pricing TP35 14 Aug 2011

Type	Group Branch Name	Formula	Limit (MW)	Solution (MW)	% Binding	Run Time
Provisional	Bunnythorpe_WDV1.1_BPE_WDV2.1_BPE_WDV2_BPE_LN	.856*BPE_WDV2.1+1.046*BPE_WDV1.1 <=	73.86	73.86	100	15/08/2011
Provisional	BPE_WDV2.1_BPE_WDV1.1_BPE_WDV1_BPE_LN	.856*BPE_WDV1.1+1.046*BPE_WDV2.1 <=	73.86	73.859	100	15/08/2011
Final	BPE_WDV1.1_BPE_WDV2.1_BPE_WDV2_BPE_LN	.856*BPE_WDV2.1+1.046*BPE_WDV1.1 <=	74.9	73.861	98.61	16/08/2011
Final	BPE_WDV2.1_BPE_WDV1.1_BPE_WDV1_BPE_LN	.856*BPE_WDV1.1+1.046*BPE_WDV2.1 <=	73.86	73.86	100	16/08/2011

Source: WITS website

Notes:
1. Provisional: HSW price relaxation factor has not been applied
2. Final: HSW price relaxation factor has been applied

2.5 Table 2 presents the power flow data across the two lines, and their characteristics, as occurred during trading period 35 on 14 August 2011. The data shows that these two lines are almost the same. The slight difference in power flow was due to the slight difference in susceptances.

Table 2 Comparison between Bunnythorpe-Woodville transmission line 1 and 2

Arc ID	Trading Day	Trading Period	Run Type	Flow In	Flow Out	Run Time	MW Max	Resistance (pu)	Susceptance (pu)
BPE_WDV1.1	14/08/2011	35	F	38.835	38.312	16/08/2011 10:48	69.8	0.03371	-11.01796
BPE_WDV2.1	14/08/2011	35	F	38.831	38.831	16/08/2011 10:48	69.8	0.03371	-11.01671

Source: Electricity Authority

Notes:
1. Data for 14 August 2011 TP35

3 Other findings

3.1 The event on 14 August 2011 triggered an investigation into the way SFT applies transmission security constraints. The Authority discovered that under SFT, two or more similar constraints would be applied to parallel transmission lines which are connected to the same bus, and which have similar characteristics.

3.2 Under certain conditions, one of these constraints could be binding, causing a HSW price situation. With the constraint(s) applied to other parallel circuit(s) being very similar to the binding constraint, the application of the HSW price relaxation factor on a binding constraint can be ineffective. As a result, the value of the binding constraint cannot therefore be relaxed to the maximum level of the HSW price relaxation factor (1 MW or 1% of the right hand side parameter in the constraint equation, whichever is greater).

3.3 Prior to SFT, only one constraint would have been applied to all the parallel circuits. Had this constraint been binding and causing a HSW price situation, the application of the HSW price relaxation factor would have relaxed the constraint value by 1 MW or 1% of RHS (whichever is greater), having the intended effect.

4 Other incidents

4.1 Another incident of this type between Bunnythorpe and Woodville occurred on 18 August 2011, during trading period 42.

4.2 On 2 September 2011, the Authority received a letter from Contact Energy (Contact), in which Contact raised this issue with the Authority. The Authority forwarded the letter to the system operator for comment.

4.3 On 12 September 2011, the system operator responded to Contact's letter stating that the system operator "*creates and applies a similar security constraint to each circuit as per normal practice*" and "*the HSW methodology worked as intended and the result reflects the real market conditions on the day*". The system operator subsequently recognised that there is a problem.

4.4 Table 3 presents the constraints applied on 18 August 2011 to the Bunnythorpe - Woodville circuits by SFT, and the constraints that would have been applied to the Bunnythorpe - Woodville circuits prior to the introduction of SFT.

Table 3 Examples of constraints applied on parallel lines prior to SFT and by SFT

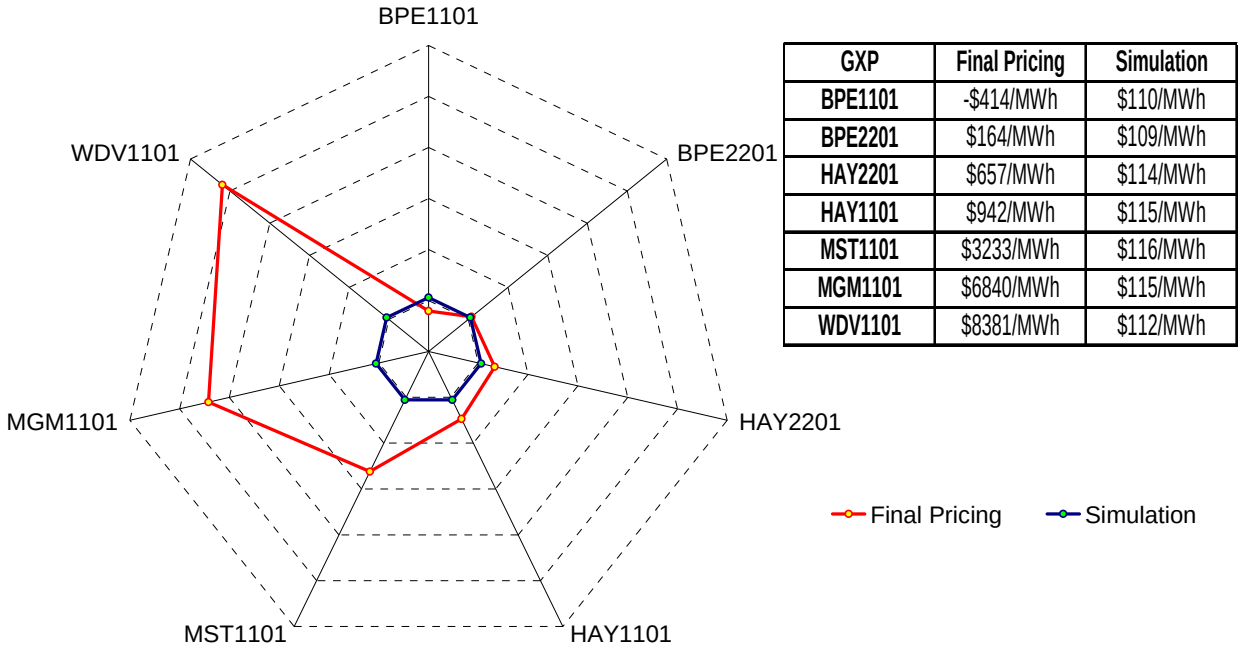
Description	Constraints applied before SFT	SFT Constraints applied
The effect of this constraint is to manage flows through Bunnythorpe_Woodville 1 or 2 for a contingency of either Bunnythorpe_Woodville circuits during HVDC south transfer, high Wellington load and/or low TAP and Wellington generation with the Te Apiti Runback Disabled.	**BPE_WDV_1&2_TAP_Runback_Disabled_W_P_2A:** 1.05 * BPE_WDV1.1 + 0.85 * BPE_WDV2.1 <= 69	**BPE_WDV2.1__BPE_WDV1.1__BPE_WDV1__BPE__LN:** .85 * BPE_WDV2.1 + 1.05 * BPE_WDV1.1 <= 73 **BPE_WDV1.1__BPE_WDV2.1__BPE_WDV2__BPE__LN:** .85 * BPE_WDV1.1 + 1.05 * BPE_WDV2.1 <= 73
The effect of this constraint is to manage flows through Arapuni-Hamilton 1 and 2 for a contingency of Arapuni-Hamilton 2 or 1 during high ARI generation. Arapuni Runback Scheme enabled.	**ARI_HAM_1_and_2_ARI_RUNBACK_ENABLED_W_P_1A:** 1.42 * ARI_HAM2.1 + 0.49 * ARI_HAM1.1 <= 87	**ARI_HAM2.1__ARI_HAM1.1__$ARIHAM1__HAM__LN:** .559 * ARI_HAM1.1 + 1.407 * ARI_HAM2.1 <= 84.6 **ARI_HAM1.1__ARI_HAM2.1__$ARIHAM2__HAM__LN:** .561 * ARI_HAM2.1 + 1.41 * ARI_HAM1.1 <= 84.7

Source: System Operator and WITS websites

Notes:
1. The first set of SFT constraints was applied for TP42 18 August 2011-09-19
2. The second set of SFT constraints was applied for TP23 18 May 2011-09-19

4.5 If only one constraint was applied, as would have occurred prior to SFT, the pricing effect for trading period 35 on 14 Aug 2011 would have been significantly improved after applying the HSW price relaxation factor. Figure 1 illustrates the comparative pricing effects between multiple and single constraint applications. With only one constraint, the HSW price situation disappears when the HSW price relaxation factor is applied (Table 4). This proves that the application of multiple constraints by SFT has very significant effect on final prices in the electricity market.

Figure 1 Pricing effect of multiple and single constraint application



GXP	Final Pricing	Simulation
BPE1101	-$414/MWh	$110/MWh
BPE2201	$164/MWh	$109/MWh
HAY2201	$657/MWh	$114/MWh
HAY1101	$942/MWh	$115/MWh
MST1101	$3233/MWh	$116/MWh
MGM1101	$6840/MWh	$115/MWh
WDV1101	$8381/MWh	$112/MWh

Source: Electricity Authority

Notes:
1. Final Pricing: two constraints are applied
2. Simulation: only one constraint is applied

Table 4 Final pricing constraint vs. simulation constraint

Case	Branch Constraint	LHS (MW)	Sense	RHS (MW)	Price ($/MWh)
Final Pricing	BPE_WDV1.1__BPE_WDV2.1__BPE_WDV2__BPE__LN	73.86	<=	74.9	0
(multiple constraints)	BPE_WDV2.1__BPE_WDV1.1__BPE_WDV1__BPE__LN	73.86	<=	73.86	9960.96
Simulation	BPE_WDV1.1__BPE_WDV2.1__BPE_WDV2__BPE__LN	74.78	<=	74.9	0
(Single constraint)	BPE_WDV2.1__BPE_WDV1.1__BPE_WDV1__BPE__LN	N\A	N\A	N\A	N\A

Source: Electricity Authority

Notes:
1. The price is the shadow price of the constraint. The price is positive if constraint binding and zero if constrain is not binding. The higher the price, the greater the HSW price effect.
2. Simulation case is run using vSPD.

5 Conclusion

5.1 With the application of SFT, different but very similar constraints can be applied to parallel transmission lines. If one of these constraints binds and causes a HSW price situation, the current methodology of HSW price relaxation may not work as intended.

5.2 The multiple constraint application on parallel transmission lines may have very significant impact on final prices as illustrated for the case of trading period 35 on 14 Aug 2011.

6 Next steps

6.1 The Authority is working with the system operator to resolve this issue.

6.2 On 15 September 2011, the Authority held a meeting with the system operator, NZX and Contact to discuss this issue. The system operator recognised that the current application of SFT may reduce the effect of the HSW price relaxation methodology. The system operator agreed to investigate the scope of the issue.

6.3 On 26 September 2011, the authority received an email from the system operator listing parallel transmission lines that are similar but not identical. However, the information was not detailed enough for the Authority to decide if a Code change was warranted.

6.4 Accordingly on 29 September 2011, the Authority sent an email to the system operator requesting more details.

6.5 The system operator sent more data to the Authority on 18 Oct 2011.

6.6 The data showed that there are at least fifteen pairs of parallel transmission lines that may have the same issue with SFT security constraints as demonstrated in the Bunnythorpe-Woodville case above.

6.7 Three solutions have been identified:

(a) reducing the number of decimal places of branch data (resistance, reactance data) sent by the grid owner to the system operator. This would make very similar, but not identical, transmission lines identical in SPD. The system operator does not consider it appropriate for them to reduce the resolution of the offer received from the grid owner.

(b) modify SFT to create only one constraint for parallel transmission lines. This option was not supported by the system operator in the meeting because this may require software changes. Typically this could involve a complicated, and costly, process of software re-coding, testing and auditing.

(c) change the Code in relation to the HSW price methodology to accommodate the SFT constraint issue. This is currently the preferred option and is being considered by the Authority.

Table 5 List of similar but not identical parallel transmission lines

Branch Name	Capacity (MW)	Resistance (pu)	Susceptance (pu)	Power flow difference
ARI_HAM1.1	62	0.08615	-4.76317	0.57%
ARI_HAM2.1	62	0.0866	-4.7362	
AVI_BEN1.1	247	0.0032	-63.41037	0.08%
AVI_BEN2.1	247	0.0032	-63.46353	
BOB_HAM1.1	61.92	0.13272	-3.06374	0.01%
BOB_HAM2.1	61.92	0.13273	-3.06344	
BPE_BRK1.1	713	0.00496	-23.25584	0.19%
BPE_BRK2.1	713	0.00497	-23.21198	
BPE_HAY1.1	335.33	0.02184	-9.14762	0.02%
BPE_HAY2.1	335.33	0.02184	-9.14916	
BPE_TKU1.1	335	0.02992	-6.68216	0.06%
BPE_TKU2.1	335	0.0299	-6.68595	
BPE_WDV1.1	69.8	0.03371	-11.01796	0.01%
BPE_WDV2.1	69.8	0.03371	-11.01671	
COL_HOR2.1	37	0.23684	-1.79316	0.04%
COL_HOR3.1	37	0.23675	-1.79388	
CYD_TWZ1.1	610	0.00138	-60.60662	0.04%
CYD_TWZ2.1	610	0.00138	-60.5823	
CYD_TWZ1.2	470	0.00789	-10.57657	0.00%
CYD_TWZ2.2	470	0.00789	-10.57657	
HLY_OHW1.1	764	0.00116	-96.78742	0.16%
HLY_OHW2.1	764	0.00116	-96.63104	
INV_ROX1.1	382	0.01842	-8.65973	0.39%
INV_ROX2.1	382	0.01809	-8.69346	
KIK_STK1.1	291	0.0073	-22.35397	0.04%
KIK_STK2.1	291	0.0073	-22.34427	
OHW_OTA1.1	671	0.00666	-22.59622	0.39%
OHW_OTA2.1	671	0.00669	-22.50919	
OTA_WKM1.1	323	0.03507	-5.69876	0.07%
OTA_WKM2.1	323	0.03509	-5.69497	
TKU_WKM1.1	335	0.01248	-16.0073	0.54%
TKU_WKM2.1	335	0.01255	-15.92185	

Source: Electricity Authority

Glossary of abbreviations and terms

Act	Electricity Industry Act 2010
Authority	Electricity Authority
Code	Electricity Industry Participation Code 2010
Contact	Contact Energy Limited
GXP	Grid exit point
MW	Megawatt
MWh	Megawatt hour
SPD	Scheduling, Pricing and Dispatch
vSPD	Vectorised Scheduling, Pricing and Dispatch