Bay of Plenty spring washer and the reduced SPD model experiment

Presentation by the system operator to the CIG
and
Paper by Graeme Everett

Background

An issue raised for the Constraints issues Group to consider was how accurately SPD inputs reflected the true characteristic of the transmission network and what the impact might be if it did not. A related issue concerned the provision of an explanation as to why the prices had occurred in the way they did during trading period 36 on 24 April 2004.

The CIG was informed that a full audit of all the inputs into the SPD model would be a massive task. However, the CIG considered that it might be possible to isolate the Tuaranga region within the SPD model (reduced SPD) and establish if the effects seen in trading period 36 could be analysed and understood through this experiment.

The system operator built and ran the reduced SPD model and provided the results and Transpower's conclusions to the CIG. Some CIG members did not agree with Transpower's conclusions and believed that the results could be interpreted to support the opposite conclusion.

To resolve the difference of opinion the CIG has recommended to the Electricity Commission that an expert is engaged to provide a view on the correct conclusions which can be drawn from the experiment.

The presentation given to the CIG is provided below together with a paper from Graeme Everett which expresses a different point of view.

September 2004

Presentation by the system operator to the CIG regarding the reduced SPD model experiment

Overview

- Tests were conducted with
  - Full NZ model
  - BOP isolated with unlimited generation at ATI, OHK & KIN at 50$/MWhr (ATI_WKM, OHK_WRK, ARI_KIN1, ARI_KIN2 removed)
- Test 1: Load at MTM increased (to 30MW) until TGA_TRK_1_S_P constraint is violated in the full NZ model. Same load inputs (30MW at MTM) were then applied to the isolated BOP model.
  - Results in Table 1
- Test 2: The load conditions in the final pricing solution for the full NZ model (tp 36) were applied to the isolated BOP model.
  - Results in Table 2
  - Price plots in slides 6 and 7

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Observations

- Test 1: (Results in Table 1)
  - Some nodal prices are slightly different
  - The dominant component of price is the constraint shadow cost, which is set by the CVP (120000$/MW)
  - Generation at ATI and KIN not used
  - OHK generation is increased
- Test 2: (Results in Table 2)
  - The security constraint is binding in the full NZ model
  - The security constraint is not binding with BOP isolated and with unlimited generation at OHK and ATI
  - Nodal prices are set by the marginal generators at ATI and OHK at 50$/MWhr and include the impact of losses with no obvious constraints or impedance artifacts
  - Price plots given in slides 6 and 7
  - Unlimited generation and no impact from rest of the grid allowed power to be re-routed to avoid the binding of any constraints

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Table 1: Price comparison with an infeasible constraint

	Full grid			Small grid		
Bus	Price	GenMW	LoadMW	Price	GenMW	LoadMW
ATI2201	88.88249	57	0	-8.24421	0	0
EDG0331	1147.061	0	22.994	1044.998	0	22.994
EDG1005	3122.75	0	0	3024.321	0	0
EDG1101	6256.591	0	0	6170.83	0	0
EDG2201	1147.061	0	0	1043.988	0	0
KAW0111	944.3441	0	23.624	858.2763	0	23.624
KAW0112	944.3441	0	69.872	854.6348	0	69.872
KAW0113	944.3441	0	74.742	854.4809	0	74.742
KAW1101	944.3441	0	0	852.7207	0	0
KAW2201	944.3441	0	0	850.3111	0	0
KIN0111	-464.822	0	59.771	-858.762	0	59.771
KIN0112	-464.822	0	12.708	-856.357	0	12.708
KIN0331	-464.822	0	12.324	-859.131	0	12.324
KIN1001	-464.822	0	0	-853.383	0	0
KIN1101	-464.822	0	0	-851.802	0	0
LFD1101	-525.103	0	1.343	-822.381	0	1.343
LFD1102	-525.354	0	1.224	-822.391	0	1.224
MAT1101	944.3441	30.5	4.585	849.9817	30.5	4.585
MTM0111	75449.69	0	12.419	78135.63	0	12.419
MTM0331	75449.69	0	30	78184.32	0	30
MTM1101	75449.69	0	0	77296.09	0	0
OHK2201	142.4393	90	0	50	452.0117	0
OKE1101	21136.78	0	0	21381.33	0	0

	Full grid			Small grid		
Bus	Price	GenMW	LoadMW	Price	GenMW	LoadMW
OWH0111	18450.3	0	9.129	18839.56	0	9.129
OWH1101	18450.3	0	0	18644.04	0	0
PKE1101	76905.66	0	0	78541.16	0	0
ROT0111	-632.458	0	18.568	-801.883	0	18.568
ROT0331	-632.458	0	23.717	-802.739	0	23.717
ROT1101	-632.458	0	0	-791.099	0	0
ROT1102	-632.458	0	0	-791.269	0	0
TGA0111	80044.21	0	17.724	81899.92	0	17.724
TGA0331	80044.21	33	57.219	82028.71	33	57.219
TGA1101	80044.21	0	0	81783.7	0	0
TKH0111	944.3441	0	1.124	925.66	0	1.124
TKH0501	944.3441	0	0	915.7036	0	0
TMI0331	52396.18	0	16.859	54061.36	0	16.859
TMI1101	52396.18	0	0	53791.43	0	0
TRK0111	-632.458	0	5.699	-778.805	0	5.699
TRK1001	-697.367	0	0	-838.52	0	0
TRK1002	-736.399	0	0	-878.613	0	0
TRK1101	-632.458	0	0	-771.975	0	0
TRK2201	-75.2736	0	0	-198.553	0	0
WAI0111	944.3441	0	6.536	873.9844	0	6.536
WAI0501	944.3441	0	0	877.8557	0	0
WAI1101	944.3441	0	0	865.6588	0	0

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Table 2: Price comparison with a binding constraint

	Full			Small		
Bus	Price	GenMW	LoadMW	Price	GenMW	LoadMW
EDG0331	179.7372	0	22.994	51.51261	0	22.994
EDG1005	378.2352	0	0	51.45566	0	0
EDG1101	693.965	0	0	51.48856	0	0
KAW0112	160.4721	0	69.872	51.8482	0	69.872
KAW1101	160.1127	0	0	51.73208	0	0
KAW2201	159.6602	0	0	51.5859	0	0
KIN0331	24.59586	0	12.324	54.37367	0	12.324
KIN1101	24.47517	0	0	54.10686	0	0
LFD1102	15.68005	0	1.224	53.03104	0	1.224
MTM1101	7799.422	0	0	52.77048	0	0
OKE1101	2212.427	0	0	52.02784	0	0
OWH1101	1946.329	0	0	52.14606	0	0
PKE1101	7923.554	0	0	52.68032	0	0
ROT1101	0	2.6741	0	51.05415	18	0
TGA1101	8247.517	0	0	52.72613	0	0
TKH0111	173.8083	0	1.124	56.15709	0	1.124
TKH0501	171.9388	0	0	55.55307	0	0
TMI0331	5478.658	0	16.859	53.0844	0	16.859
TMI1101	5451.303	0	0	52.81935	0	0
TRK1001	-6.44928	0	0	51.14731	0	0
TRK1101	0	0	0	51.1617	0	0
TRK0111	0	0	5.699	51.2208	0	5.699
ROT1102	0	0	0	51.81759	0	0

	Full			Small		
Bus	Price	GenMW	LoadMW	Price	GenMW	LoadMW
TRK2201	55.36109	0	0	51.13955	0	0
WAI0501	164.8322	0	0	53.25695	0	0
KIN0112	24.45802	30	12.708	54.06893	30	12.708
KAW0113	160.4432	0	74.742	51.83887	0	74.742
TRK1002	-10.3271	0	0	51.14404	0	0
KIN1001	24.4692	0	0	54.09366	0	0
KAW0111	161.1558	0	23.624	52.06912	0	23.624
KIN0111	24.58792	0	59.771	54.35612	0	59.771
LFD1101	15.72659	0	1.343	53.03276	0	1.343
MAT1101	159.5984	30.5	4.585	51.56592	30.5	4.585
MTM0111	7884.135	0	12.419	53.34364	0	12.419
OWH0111	1966.74	0	9.129	52.6929	0	9.129
ROT0331	0	0	23.717	51.5309	0	23.717
TGA0111	8259.237	0	17.724	52.80105	0	17.724
TGA0331	8272.225	33	57.219	52.88409	33	57.219
ATI2201	69.36932	45	0	50	268.5339	0
ROT0111	0	0	18.568	52.20862	0	18.568
MTM0331	7889.047	0	21.574	53.37687	0	21.574
EDG2201	179.5634	0	0	51.4628	0	0
WAI0111	164.1053	0	6.536	53.02209	0	6.536
OHK2201	74.51225	60	0	50	104.1962	0
WAI1101	162.542	0	0	52.517	0	0

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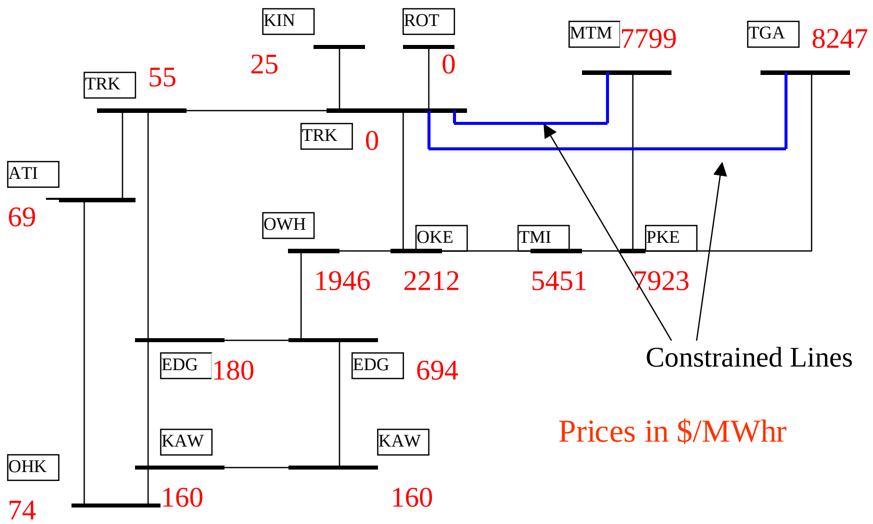
With full network



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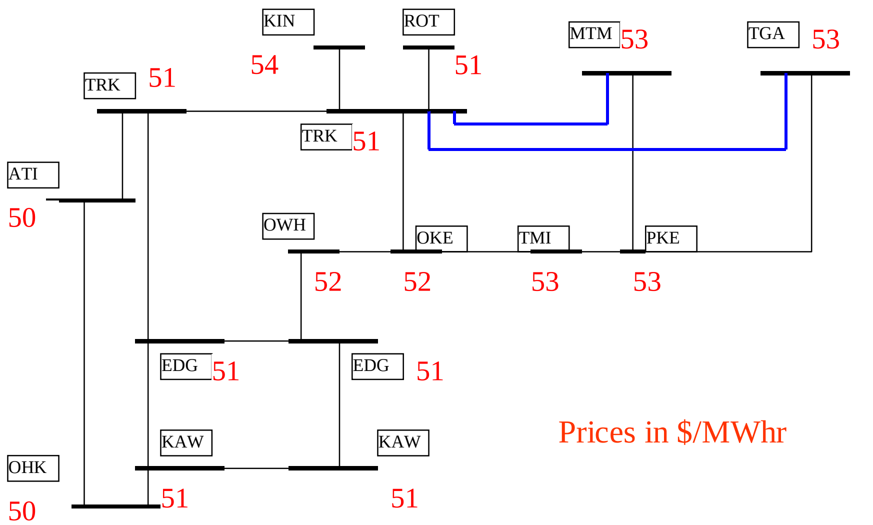
Slide 6

With BOP isolated (unlimited generation at ATI, OHK, KIN)



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Slide 7

BOP Spring washer
Paper by Graeme Everett

The Constraints Issues Group (CIG) has been established by the Electricity Commission to investigate a number of concerns expressed by market participants in relation to a series of very high prices that have been published in the electricity market in 2004. The credibility of the nodal pricing model is being seriously questioned by participants who are not prepared to simply trust the outputs from a computer model, and feel indignant that prices many times higher than generation offers have, to date, not been adequately explained.

Transpower has performed an experiment in order to identify the main cause of the high provisional prices observed in the Tauranga region on April 24th. The purpose of this experiment is to adequately explain how these prices could be generated by the SPD model, thereby defending the integrity of the model.

Transpower had already produced a description of what changes in dispatch had occurred, and how these changes amounted to the prices published by SPD. But lacking in Transpower's description was a coherent explanation of WHY the changes occurred.

This paper explains seeks to answer this important question.

Experiment with SPD

The NZ High Voltage transmission network is a complex grid, comprising numerous links and loops. Spring washers are known to exist in the presence of a transmission loop, when the flow along one or more of the circuits comprising the loop has reached its upper limit. It was postulated that if a simple loop involving the constrained circuits into Tauranga could be identified that caused the high prices at Tauranga, then analysis of the reactance values of the components of that loop would explain how the spring washer worked.

Transpower produced a small version of the SPD model with only the nodes in the BOP included. The rest of the grid was isolated at Ohakuri, Atiamuri and Kinleith, and infinite generators were placed at these nodes instead. This small grid effectively relaxed all of the loop constraints in the SPD model, except for those in the BOP.

The demand at Mt Maunganui was increased in 100 kW increments from 21.574 MW to 23.074, and SPD solved each time. Prices remained at similar levels until the load reached 22.17 MW, presumably the point that the group constraint involving circuits between Tarukenga and Mt Maunganui and Tauranga reached its upper limit. As the load was increased beyond 22.17 MW prices were observed consistent with the spring washer effect.

Transpower observed that when SPD was solved with the load at Mt Maunganui of 21.574 MW with the full grid then prices consistent with a spring washer were published, and noted that no such effect occurred with the small grid. They maintain that this is evidence that the rest of the grid has a material influence on the spring washer in the BOP, and that in fact there were multiple loops all over the country that materially affected the spring washer mechanism in the BOP. Transpower concluded that there is no simple loop that can be identified that was responsible for the high prices in the BOP, and that the questions raised by industry participants regarding the credibility of SPD can not be answered. It is unclear how Transpower think that industry participants' concerns should be placated, or whether there is even any need to do so.

However I disagree with Transpower, for the following reasons:

1. It is, of course, true that transmission loops outside the BOP affect the transmission flows within the BOP. Therefore it is very unlikely that the small BOP grid described above will produce identical results to the large grid – and the fact that identical results were not observed provides no proof that the small grid does not reflect flows within the BOP.

2. It makes sense that a slightly higher load was required at Mt Maunganui to produce a spring washer in the small grid than in the large grid because the small grid is less constrained than the large grid.

3. The small grid did produce a spring washer situation with prices that were very similar to the spring washer from the large grid.

4. Transmission flows along the Tarukenga to Mt Maunganui and Tauranga circuits reached their upper limits in both the small and large grid spring washer situations.

5. Since the small grid produced a spring washer, there must be a loop within the small grid that created the spring washer.

6. Analysis of the arc flows from the small and large grids with spring washer situations would go a long way to prove whether the loops were similar in both cases. Transpower are the only party that has this arc flow data available to them.

7. In the unlikely event that it can be demonstrated that the loop(s) that created the spring washer in the small grid had no bearing on the spring washer in the large grid, the fact remains that the loop(s) in the small grid created a spring washer. This can only be brushed away as irrelevant if it can be proved that the loop(s) that created the spring washer in the small grid can NEVER create a spring washer in the large grid.

8. In any case the loop(s) that created the spring washer in the small grid can be quite easily analysed (since they involve only a few nodes) to verify the integrity of the SPD model.

9. If the analysis of point 8 shows flaws in either the data used to reflect grid characteristics, or the equations within SPD, then the credibility of the SPD model will have been shattered. On the other hand if the data and equations support the pricing outcomes, then a suitable explanation of why the spring washer occurred will have been found.

Next Steps

If the assessment outlined above reveals any flaws then this will reflect badly on any past audits. Therefore it is not appropriate for the assessment to involve the regular auditors of SPD as they have an incentive NOT to find any flaws. For similar reasons it is not appropriate for any other advisors to Transpower on areas of work related to the SPD model to carry out this assessment. Suitably qualified, and demonstrably independent consultants should be engaged to carry out this work.. Whoever does the work will be reliant on Transpower for the provision of data, and use of the SPD model (both the full version and the small BOP grid – and any other version that may be required).

Graeme Everett
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13th September 2004