Non-Physical Loss Handling

A Market Clearing Engine Study of the NEMS

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About the Author

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Lu Feiyu joined Energy Market Company, the market operator for the National Electricity Market of Singapore, as a Market Analyst in March 2002. His primary responsibilities are the daily operation of the market and review of its outcome, dissemination of market information and in-house application development. Feiyu is also one of the company's pioneers in conducting local and international training and educational forums about the market clearing engine, specifically its formulations, pricing methodology and system enhancements. He is actively involved in enhancing the market system by identifying gaps between business processes and the market system, suggesting improvements and preparing and performing user acceptance tests. He also contributes to the market rule change process through technical reviews of the proposed changes.

Feiyu holds a Bachelor degree in Electrical Engineering from Tianjin University (China) and a Master of Engineering degree in Electrical and Electronic Engineering from Nanyang Technological University (Singapore).

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1.0 Introduction

This paper studies the reasons for non-physical loss handling in the National Electricity Market of Singapore (NEMS) and focuses on the instances where it is triggered by a negative marginal offer price. It describes how the NEMS approximates the quadratic loss function using a model of the transmission circuit with nine constant nodes and eight linear segments and follows the solution step by step. A case study of an actual negative price case on 6 October 2003 is included.

2.0 Non-Physical Loss in the MCE

2.1 What is non-physical loss?

The objective function of the linear programme (LP) solver in the NEMS is to maximise the social welfare of dispatching energy, reserve and regulation over the Singapore power system. To simplify the analysis, only energy is considered. The objective function effectively becomes:

Maximise (∑PurchaseBidPrice×PurchaseBlock – ∑GenerationOfferPrice×GenerationBlock)

The PurchaseBidPrice is fixed at $50,000/MWh, and the ∑PurchaseBlock is equal to the system load forecast. Therefore, for a given period, both are constant values. Hence, the GenerationOfferPrice and the GenerationBlock become the determinant factors.

The number of GenerationBlock dispatched is a function of the total generation of the NEMS. The higher the generation, the greater the number of GenerationBlock are dispatched and, subsequently, the higher the offer price that is cleared. As the generation comprises the load forecast and the transmission loss, the solver will, in most cases, attempt to minimise the losses on the branches and, hence, minimise the total number of GenerationBlock dispatched and maximise the total objective function value.

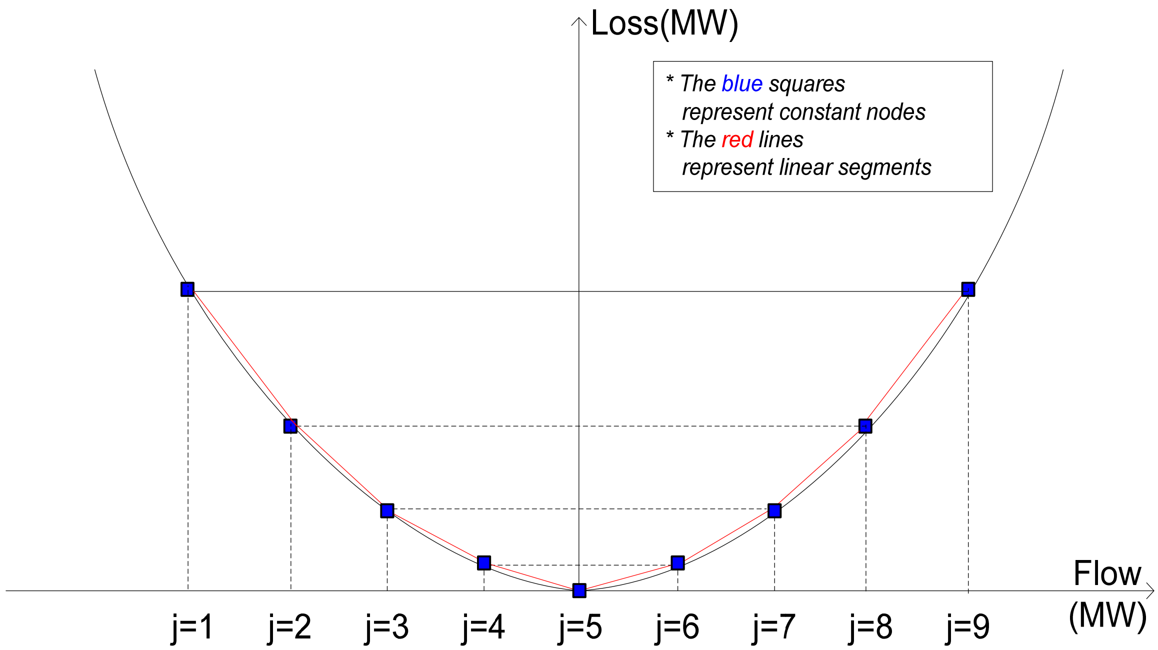
However, an anomaly may occur when the marginal offer price is negative. In order to maximise the total objective function, the solver will attempt to maximise the generation. As such, the solver will select the largest possible loss it can incur; in the case of the NEMS, non-adjacent nodes will be selected to produce a larger-than-normal loss for a certain flow. This anomaly is referred to as non-physical loss (NPL) and, if left unresolved, would result in considerable errors in the calculation of transmission loss and of energy dispatch during negative prices.

Theoretically, when the marginal price is zero, NPL may also appear because over-dispatch does not impact the objective function value when the nodal prices are zero throughout the system. Another possible occurrence of NPL is in tandem with the spring-washer effect, where any extra MW incurred from NPL enables more flow on the parallel paths. If the cost of NPL is less than the benefit gained from the additional flow, the solver will choose NPL. This more complicated scenario requires a separate discussion and is not covered in this paper.

2.2 What is the NPL problem in the MCE?

Different market models employ different methodologies to handle NPL, based on the specific market design, and especially on the transmission circuit modelling. For example, in Australia, National Electricity Market Management Company (NEMMCO) employs NPL Run in which the multi-segment interconnector loss model for each interconnector is effectively removed and replaced with a static loss factor; and the interconnector flow targets are clamped to within ±250MW of their initial interconnector flows to prevent actual losses from deviating too greatly from those determined using the static loss factor.

The NEMS takes a different approach. The market clearing engine (MCE) models the transmission circuit using nine constant nodes and eight linear segments. Thus the quadratic loss function (Loss = Resistance * Flow ^ 2) is approximated by a series of linear segments, as depicted in the figure:


Loss(MW)
* The blue squares represent constant nodes
* The red lines represent linear segments
Flow (MW)
j=1
j=2
j=3
j=4
j=5
j=6
j=7
j=8
j=9

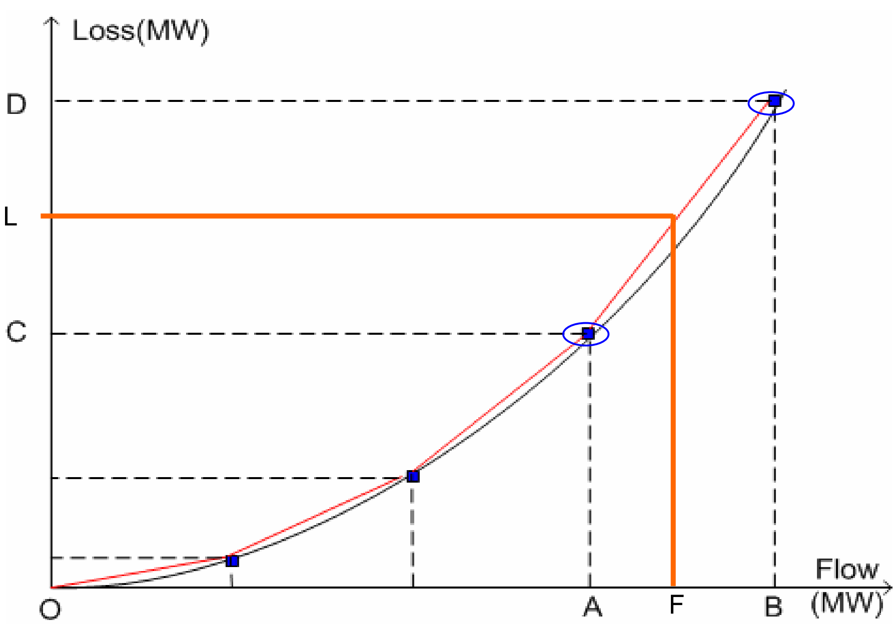
The mathematical expression for the above model is:

$$\begin{cases} \text{LineFlow}_k = \sum_{j \in \text{DISCRSUB}_k} \text{LineFlowConst}_{k,j} \times \text{Weight}_{k,j} \\ \qquad + \text{DeficitWLineFlow}_k - \text{ExcessWLineFlow}_k \\ \text{LineLoss}_k = \sum_{j \in \text{DISCRSUB}_k} \text{LineLossConst}_{k,j} \times \text{Weight}_{k,j} \\ \sum_{j \in \text{DISCRSUB}_k} \text{Weight}_{k,j} = 1 \end{cases}$$

$$\{k \in \text{LINES}, k \notin \text{ARTIFICIALLINES1} \cup \text{ARTIFICIALLINES3}\}$$

A new variable, Weight, is introduced to compose the best solution by combing through the nine variables of each of the constant nodes to find the best two nodes for each solution.

Under a positive nodal price scenario, the solver always uses the two adjacent nodes surrounding a certain flow to drive the transmission loss on a circuit. This results in an optimal solution. For example:

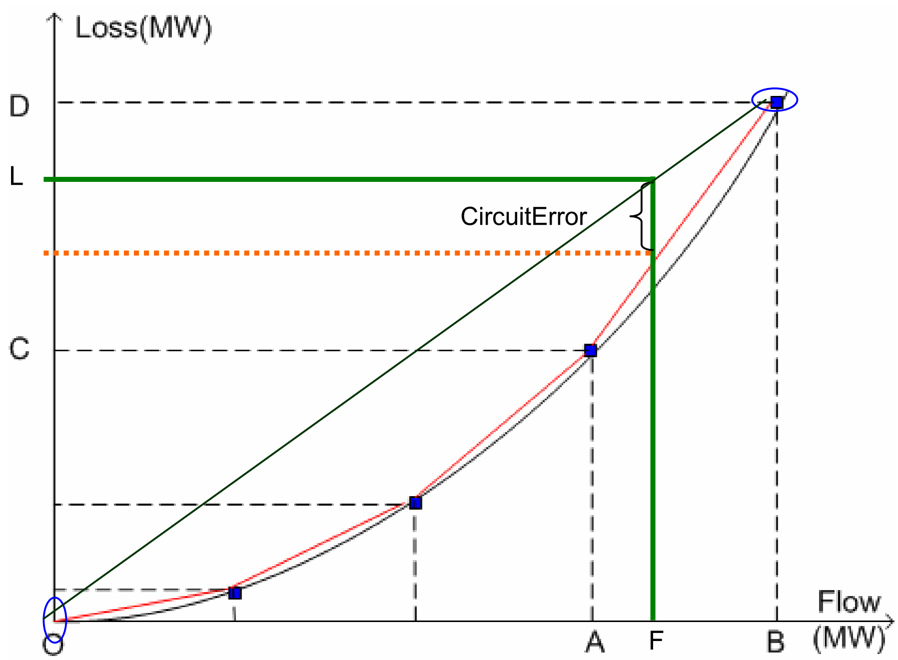


LineFlow: Flow = Weight(A,C)*A + Weight(B,D)*B

LineLoss: Loss = Weight(A,C)*C + Weight(B,D)*D

Weight: 1 = Weight(A,C) + Weight(B,D)

However, if negative nodal prices are present, the solver will produce NPL. Graphically, the loss may be derived by using non-adjacent nodes, as below:



LineFlow: Flow = Weight (O,O)* O + Weight (B,D)*B

LineLoss: Loss = Weight (O,O)*O + Weight (B,D)*D

Weight: 1 = Weight (O,O) + Weight (B,D)

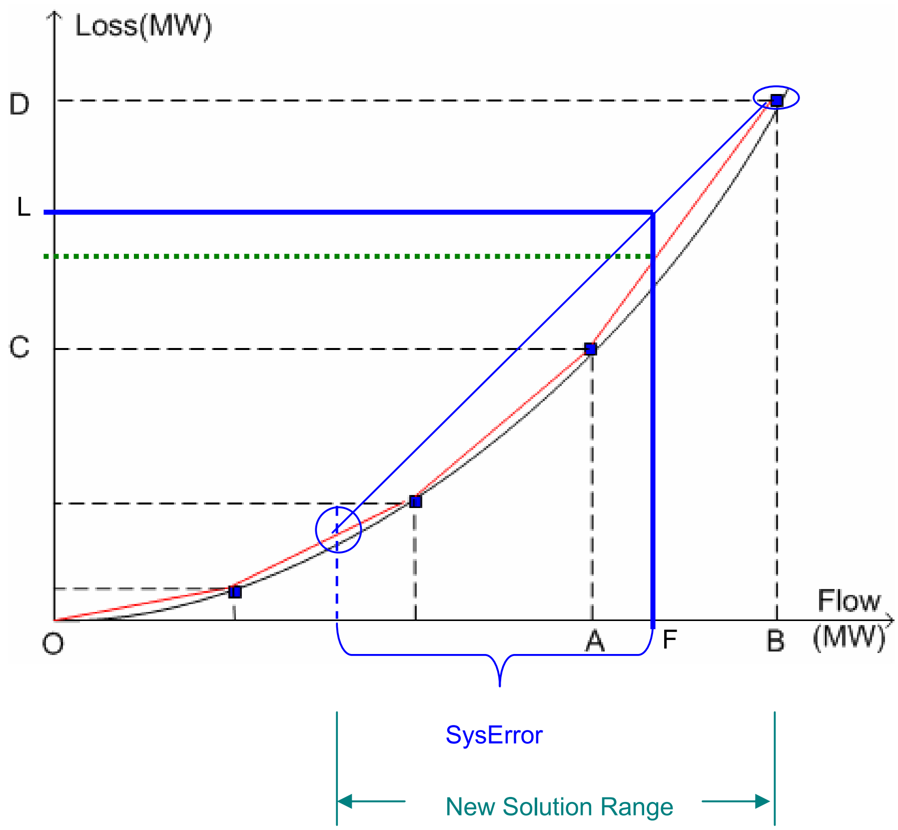
Instead of nodes (A,C) and (B,D), the solver uses origin (O,O) and node (B,D) to derive the loss. Obviously, there is an overstatement of the transmission loss, which is indicated on the above graph as CircuitError.

2.3 How does the NEMS handle NPL?

The root cause of NPL lies in the employment of non-adjacent nodes to calculate the loss. Therefore, the NEMS mitigates this problem by reducing the solution range. Its methodology is:

- Step 1: The solver checks for the presence of non-adjacent nodes whose weights are both greater than zero. If any pair is found, it indicates a possible NPL case.
- Step 2: The solver calculates the CircuitError on each transmission circuit.
- Step 3: The solver sums all of the circuit errors into the total error, called SysError.
- Step 4: The solver checks whether the SysError is within the allowable tolerance. If it is, it ignores the error and produces the results. Otherwise, it proceeds onto Step 5.

- Step 5: The solver narrows the solution range for each circuit into the intersection of original range and [(LineFlow – SysError), (LineFlow + SysError)]. All of the constant nodes within this range are kept, while the outliers are removed.



- Step 6: The solver solves the case again and begins again at Step 1.

In the case where an accurate solution can only be found after many iterations, the NEMS adopts a compromise between accuracy and performance. If the SysError is less than a certain threshold[1] or the iteration goes up to a certain number[2], the iteration will not carry on. Instead, the current result will be reported as acceptable.

A more detailed procedure of NPL handling is described in the Market Rules, as shown in Appendix A.

[1] 10MW, in the current setting of the MCE.

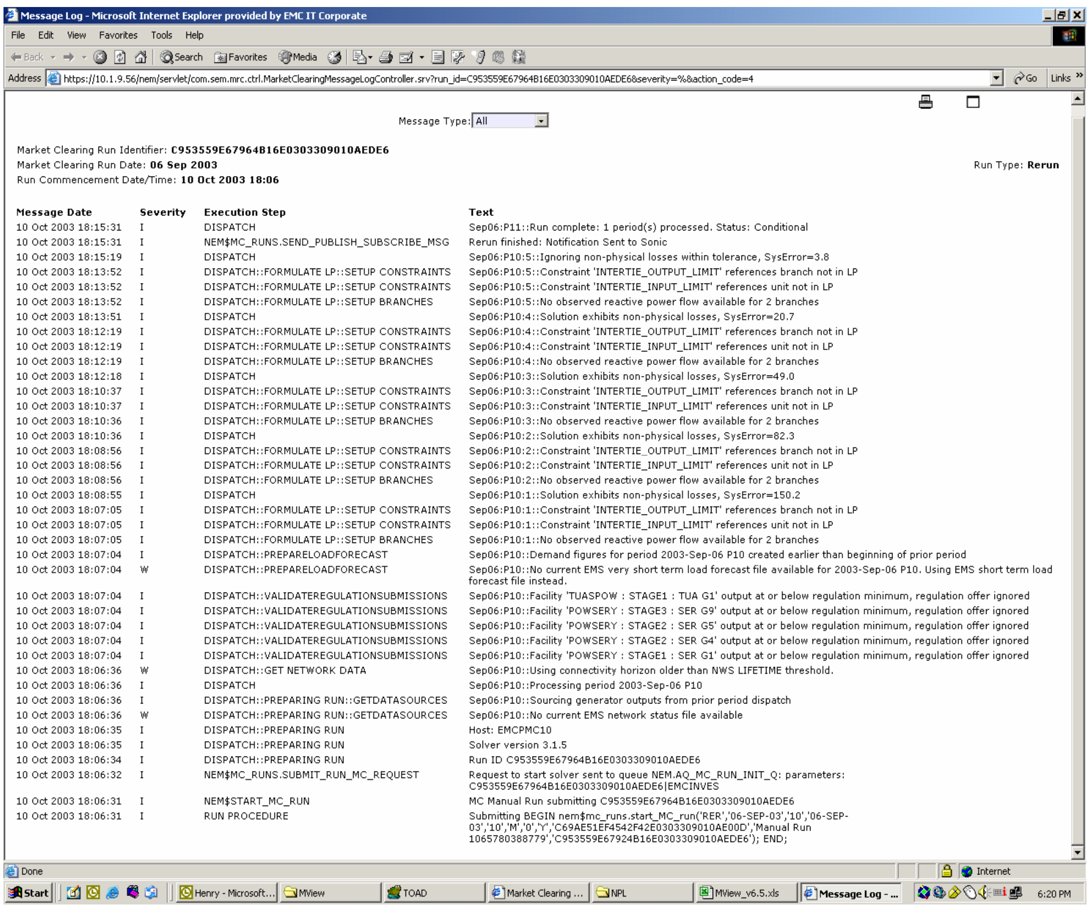
[2] 20 times, in the current setting of the MCE.

3.0 Case Study

3.1 Simulation in offline environment

To study the process of the NPL handling, a negative price case was created in an offline environment for Period 10 on 6 October 2003. A rerun was conducted with the Raw Result flag turned on so that the detailed results of each iteration could be retrieved.

As expected, the NPL process was triggered as demonstrated by the Message Log:



Message Log - Microsoft Internet Explorer provided by EMC IT Corporate

Address: https://10.1.9.56/nem/servlet/com.sem.mrc.ctrl.MarketClearingMessageLogController.srv?run_id=C953559E67964B16E0303309010AEDE6&severity=%&action_code=4

Message Type: All

Market Clearing Run Identifier: **C953559E67964B16E0303309010AEDE6**
Market Clearing Run Date: **06 Sep 2003**
Run Commencement Date/Time: **10 Oct 2003 18:06**
Run Type: **Rerun**

Message Date	Severity	Execution Step	Text
10 Oct 2003 18:15:31	I	DISPATCH	Sep06:P11::Run complete: 1 period(s) processed. Status: Conditional
10 Oct 2003 18:15:31	I	NEM$MC_RUNS.SEND_PUBLISH_SUBSCRIBE_MSG	Rerun finished: Notification Sent to Sonic
10 Oct 2003 18:15:19	I	DISPATCH	Sep06:P10:5::Ignoring non-physical losses within tolerance, SysError=3.8
10 Oct 2003 18:13:52	I	DISPATCH::FORMULATE LP::SETUP CONSTRAINTS	Sep06:P10:5::Constraint 'INTERTIE_OUTPUT_LIMIT' references branch not in LP
10 Oct 2003 18:13:52	I	DISPATCH::FORMULATE LP::SETUP CONSTRAINTS	Sep06:P10:5::Constraint 'INTERTIE_INPUT_LIMIT' references unit not in LP
10 Oct 2003 18:13:52	I	DISPATCH::FORMULATE LP::SETUP BRANCHES	Sep06:P10:5::No observed reactive power flow available for 2 branches
10 Oct 2003 18:13:51	I	DISPATCH	Sep06:P10:4::Solution exhibits non-physical losses, SysError=20.7
10 Oct 2003 18:12:19	I	DISPATCH::FORMULATE LP::SETUP CONSTRAINTS	Sep06:P10:4::Constraint 'INTERTIE_OUTPUT_LIMIT' references branch not in LP
10 Oct 2003 18:12:19	I	DISPATCH::FORMULATE LP::SETUP CONSTRAINTS	Sep06:P10:4::Constraint 'INTERTIE_INPUT_LIMIT' references unit not in LP
10 Oct 2003 18:12:19	I	DISPATCH::FORMULATE LP::SETUP BRANCHES	Sep06:P10:4::No observed reactive power flow available for 2 branches
10 Oct 2003 18:12:18	I	DISPATCH	Sep06:P10:3::Solution exhibits non-physical losses, SysError=49.0
10 Oct 2003 18:10:37	I	DISPATCH::FORMULATE LP::SETUP CONSTRAINTS	Sep06:P10:3::Constraint 'INTERTIE_OUTPUT_LIMIT' references branch not in LP
10 Oct 2003 18:10:37	I	DISPATCH::FORMULATE LP::SETUP CONSTRAINTS	Sep06:P10:3::Constraint 'INTERTIE_INPUT_LIMIT' references unit not in LP
10 Oct 2003 18:10:36	I	DISPATCH::FORMULATE LP::SETUP BRANCHES	Sep06:P10:3::No observed reactive power flow available for 2 branches
10 Oct 2003 18:10:36	I	DISPATCH	Sep06:P10:2::Solution exhibits non-physical losses, SysError=82.3
10 Oct 2003 18:08:56	I	DISPATCH::FORMULATE LP::SETUP CONSTRAINTS	Sep06:P10:2::Constraint 'INTERTIE_OUTPUT_LIMIT' references branch not in LP
10 Oct 2003 18:08:56	I	DISPATCH::FORMULATE LP::SETUP CONSTRAINTS	Sep06:P10:2::Constraint 'INTERTIE_INPUT_LIMIT' references unit not in LP
10 Oct 2003 18:08:56	I	DISPATCH::FORMULATE LP::SETUP BRANCHES	Sep06:P10:2::No observed reactive power flow available for 2 branches
10 Oct 2003 18:08:55	I	DISPATCH	Sep06:P10:1::Solution exhibits non-physical losses, SysError=150.2
10 Oct 2003 18:07:05	I	DISPATCH::FORMULATE LP::SETUP CONSTRAINTS	Sep06:P10:1::Constraint 'INTERTIE_OUTPUT_LIMIT' references branch not in LP
10 Oct 2003 18:07:05	I	DISPATCH::FORMULATE LP::SETUP CONSTRAINTS	Sep06:P10:1::Constraint 'INTERTIE_INPUT_LIMIT' references unit not in LP
10 Oct 2003 18:07:05	I	DISPATCH::FORMULATE LP::SETUP BRANCHES	Sep06:P10:1::No observed reactive power flow available for 2 branches
10 Oct 2003 18:07:04	I	DISPATCH::PREPARELOADFORECAST	Sep06:P10::Demand figures for period 2003-Sep-06 P10 created earlier than beginning of prior period
10 Oct 2003 18:07:04	W	DISPATCH::PREPARELOADFORECAST	Sep06:P10::No current EMS very short term load forecast file available for 2003-Sep-06 P10. Using EMS short term load forecast file instead.
10 Oct 2003 18:07:04	I	DISPATCH::VALIDATEREGULATIONSUBMISSIONS	Sep06:P10::Facility 'TUASPOW : STAGE1 : TUA G1' output at or below regulation minimum, regulation offer ignored
10 Oct 2003 18:07:04	I	DISPATCH::VALIDATEREGULATIONSUBMISSIONS	Sep06:P10::Facility 'POWSERY : STAGE3 : SER G9' output at or below regulation minimum, regulation offer ignored
10 Oct 2003 18:07:04	I	DISPATCH::VALIDATEREGULATIONSUBMISSIONS	Sep06:P10::Facility 'POWSERY : STAGE2 : SER G5' output at or below regulation minimum, regulation offer ignored
10 Oct 2003 18:07:04	I	DISPATCH::VALIDATEREGULATIONSUBMISSIONS	Sep06:P10::Facility 'POWSERY : STAGE2 : SER G4' output at or below regulation minimum, regulation offer ignored
10 Oct 2003 18:07:04	I	DISPATCH::VALIDATEREGULATIONSUBMISSIONS	Sep06:P10::Facility 'POWSERY : STAGE1 : SER G1' output at or below regulation minimum, regulation offer ignored
10 Oct 2003 18:06:36	W	DISPATCH::GET NETWORK DATA	Sep06:P10::Using connectivity horizon older than NWS LIFETIME threshold.
10 Oct 2003 18:06:36	I	DISPATCH	Sep06:P10::Processing period 2003-Sep-06 P10
10 Oct 2003 18:06:36	I	DISPATCH::PREPARING RUN::GETDATASOURCES	Sep06:P10::Sourcing generator outputs from prior period dispatch
10 Oct 2003 18:06:36	W	DISPATCH::PREPARING RUN::GETDATASOURCES	Sep06:P10::No current EMS network status file available
10 Oct 2003 18:06:35	I	DISPATCH::PREPARING RUN	Host: EMCPMC10
10 Oct 2003 18:06:35	I	DISPATCH::PREPARING RUN	Solver version 3.1.5
10 Oct 2003 18:06:34	I	DISPATCH::PREPARING RUN	Run ID C953559E67964B16E0303309010AEDE6
10 Oct 2003 18:06:32	I	NEM$MC_RUNS.SUBMIT_RUN_MC_REQUEST	Request to start solver sent to queue NEM.AQ_MC_RUN_INIT_Q: parameters: C953559E67964B16E0303309010AEDE6|EMCINVES
10 Oct 2003 18:06:31	I	NEM$START_MC_RUN	MC Manual Run submitting C953559E67964B16E0303309010AEDE6
10 Oct 2003 18:06:31	I	RUN PROCEDURE	Submitting BEGIN nem$mc_runs.start_MC_run('RER','06-SEP-03','10','06-SEP-03','10','M','0','Y','C69AE51EF4542F42E0303309010AE00D','Manual Run 1065780388779','C953559E67924B16E0303309010AEDE6'); END;

Done | Internet

By reading the raw results from each iteration, the SysErrors in the multiple iterations can be summarised in the table:

Iteration	SysError (MW)
1	150.2
2	82.3
3	49.0
4	20.7
5	3.8

A branch that bore non-physical loss (A.RAJH-X : 230 : FHV-TF1) was observed as follows:

INVES environment DPR, P10 6-Sep-03
A.RAJH-X : 230 : FHV-TF1

SysError | NewBound | FinalResult

where NewBound = {flow – SysError, flow + SysError}

1									J					
Line	**Rating**	**X**	**R**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Result**
A.RAJH-X : 230 : FHV-TF1	500	-0.007649	0.00018	**FLOW**	-500	-375	-250	-125	0	125	250	375	500	143.378
				LOSS	0.45	0.253125	0.1125	0.028125	0	0.028125	0.1125	0.253125	0.45	0.041
Iteration 1	150.2			Weight	0.335148217	0	0	0	0	0	0	0	0.664851783	
				Flow*Weight:	-167.5741085	0	0	0	0	0	0	0	332.4258915	164.8517829
				Loss*Weight:	0.150816698	0	0	0	0	0	0	0	0.299183302	0.45

2	NewBound:	14.65178291	315.0517829						J					
Line	**Rating**	**X**	**R**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Result**
A.RAJH-X : 230 : FHV-TF1	500	-0.007649	0.00018	**FLOW**	0	0	0	0	14.65178291	125	250	315.0517829	0	143.378
				LOSS	0	0	0	0	0.003296651	0.028125	0.1125	0.185683256	0	0.041
Iteration 2	82.3			Weight	0	0	0	0	0.526776742	0	0	0.473223258	0	
				Flow*Weight:	0	0	0	0	7.71821846	0	0	149.0898312	0	156.8080497
				Loss*Weight:	0	0	0	0	0.001736599	0	0	0.087869635	0	0.089606234

3	NewBound:	74.5080497	239.1080497						J					
Line	**Rating**	**X**	**R**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Result**
A.RAJH-X : 230 : FHV-TF1	500	-0.007649	0.00018	**FLOW**	0	0	0	0	74.5080497	125	239.1080497	0	0	143.378
				LOSS	0	0	0	0	0.016764311	0.028125	0.105147934	0	0	0.041
Iteration 3	49			Weight	0	0	0	0	0.535131933	0	0.464868067	0	0	
				Flow*Weight:	0	0	0	0	39.87163669	0	111.1536968	0	0	151.0253334
				Loss*Weight:	0	0	0	0	0.008971118	0	0.048879917	0	0	0.057851035

4	NewBound:	102.0253334	200.0253334						J					
Line	**Rating**	**X**	**R**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Result**
A.RAJH-X : 230 : FHV-TF1	500	-0.007649	0.00018	**FLOW**	0	0	0	0	102.0253334	125	200.0253334	0	0	143.378
				LOSS	0	0	0	0	0.0229557	0.028125	0.0787671	0	0	0.041
Iteration 4	20.7			Weight	0	0	0	0	0.548509841	0	0.451490159	0	0	
				Flow*Weight:	0	0	0	0	55.96189943	0	90.30946959	0	0	146.271369
				Loss*Weight:	0	0	0	0	0.012591427	0	0.035562571	0	0	0.048153998

5	NewBound:	125.571369	166.971369						J					
Line	**Rating**	**X**	**R**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Result**
A.RAJH-X : 230 : FHV-TF1	500	-0.007649	0.00018	**FLOW**	0	0	0	0	0	125.571369	166.971369	0	0	143.378
				LOSS	0	0	0	0	0	0.028510674	0.056455674	0	0	0.041
Iteration 5	3.8			Weight	0	0	0	0	0	0.56985611	0.43014389	0	0	
				Flow*Weight:	0	0	0	0	0	71.55761192	71.82171414	0	0	143.3793261
				Loss*Weight:	0	0	0	0	0	0.016246982	0.024284063	0	0	0.040531045

It was noted that adjacent nodes were used in the final iteration so as to eliminate the CircuitError on this branch.

However, it is not always true that the iterations narrow down to adjacent nodes, as observed on another branch (A.RAJH-X : 230 : EHV-TF1).

INVES environment DPR, P10 6-Sep-03
A.RAJAH : 230 : EHV-TF 1

SysError NewBound FinalResult

where NewBound = {flow – SysError, flow + SysError}

1									J					
Line	**Rating**	**X**	**R**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Result**
A.RAJAH : 230 : EHV-TF 1	150	0.17822	0.00107	**FLOW**	-150	-112.5	-75	-37.5	0	37.5	75	112.5	150	38.108
				LOSS	0.24075	0.13542188	0.0601875	0.015047	0	0.01504688	0.0601875	0.135421875	0.24075	0.024
Iteration 1	150.2			Weight	0.3690597	0	0	0	0	0	0	0	0.63094028	
				Flow*Weight:	-55.358958	0	0	0	0	0	0	0	94.64104203	39.28208
				Loss*Weight:	0.0888511	0	0	0	0	0	0	0	0.151898872	0.24075

2	NewBound:	-110.9179159	189.4820841						J					
Line	**Rating**	**X**	**R**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Result**
A.RAJAH : 230 : EHV-TF 1	150	0.17822	0.00107	**FLOW**	0	-110.91792	-75	-37.5	0	37.5	75	112.5	150	38.108
				LOSS	0	0.13224782	0.0601875	0.015047	0	0.01504688	0.0601875	0.135421875	0.24075	0.024
Iteration 2	82.3			Weight	0	0.42459013	0	0	0	0	0	0	0.575409871	
				Flow*Weight:	0	-47.094652	0	0	0	0	0	0	86.31148067	39.21683
				Loss*Weight:	0	0.05615112	0	0	0	0	0	0	0.138529926	0.194681

3	NewBound:	-43.08317155	121.5168285						J					
Line	**Rating**	**X**	**R**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Result**
A.RAJAH : 230 : EHV-TF 1	150	0.17822	0.00107	**FLOW**	0	0	-43.083172	-37.5	0	37.5	75	112.5	121.5168285	38.108
				LOSS	0	0	0.0217676	0.015047	0	0.01504688	0.0601875	0.135421875	0.160747892	0.024
Iteration 3	49			Weight	0	0	0.5024207	0	0	0	0	0	0.497579263	
				Flow*Weight:	0	0	-21.645879	0	0	0	0	0	60.46425399	38.81838
				Loss*Weight:	0	0	0.0109365	0	0	0	0	0	0.079984818	0.090921

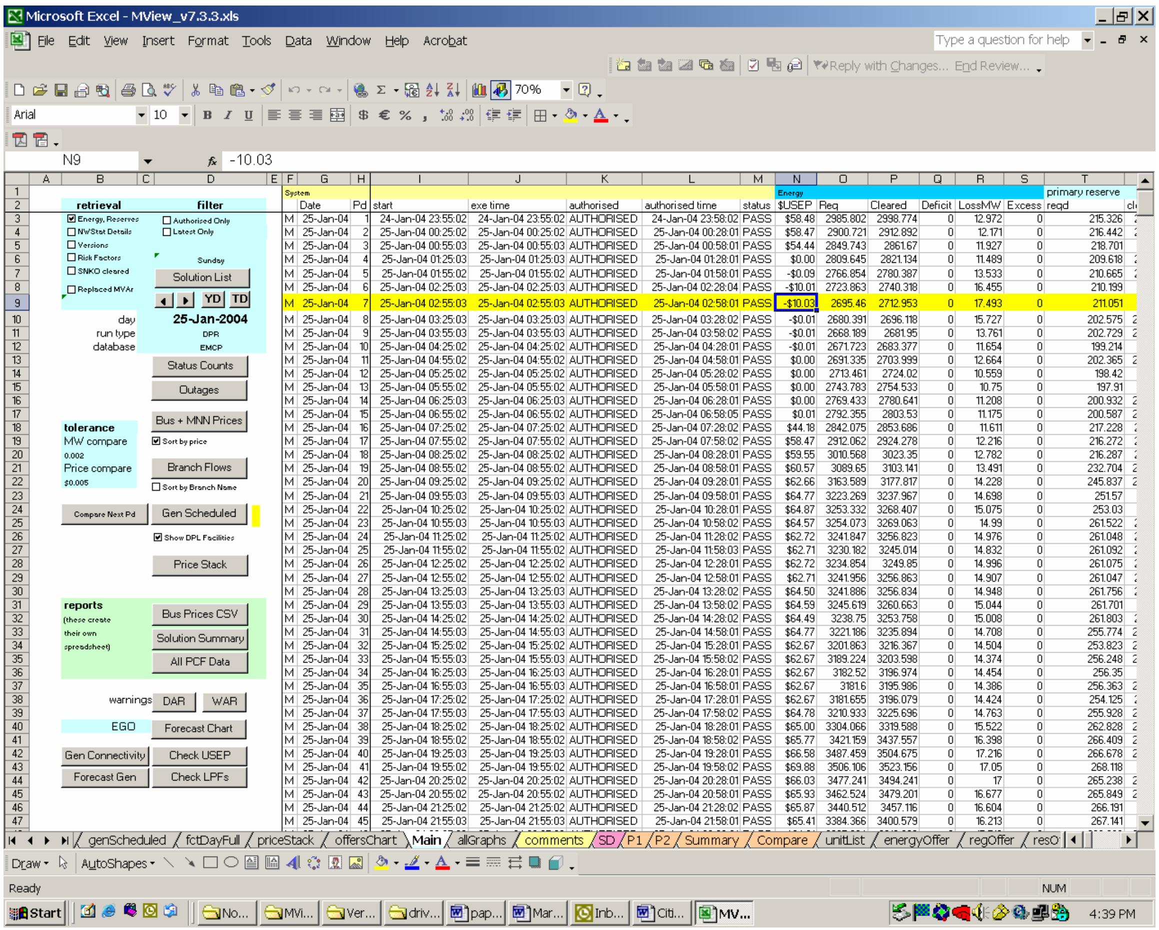
4	NewBound:	-10.1816248	87.8183752						J					
Line	**Rating**	**X**	**R**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Result**
A.RAJAH : 230 : EHV-TF 1	150	0.17822	0.00107	**FLOW**	0	0	0	-10.18162	0	37.5	75	87.8183752	0	38.108
				LOSS	0	0	0	0.004085	0	0.01504688	0.0601875	0.085904365	0	0.024
Iteration 4	20.7			Weight	0	0	0	0.504665	0	0	0	0.495334549	0	
				Flow*Weight:	0	0	0	-5.138314	0	0	0	43.49947527	0	38.36116
				Loss*Weight:	0	0	0	0.002062	0	0	0	0.0425514	0	0.044613

5	NewBound:	17.661161	59.061161						J					
Line	**Rating**	**X**	**R**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Result**
A.RAJAH : 230 : EHV-TF 1	150	0.17822	0.00107	**FLOW**	0	0	0	0	17.661161	37.5	59.061161	0	0	38.108
				LOSS	0	0	0	0	0.0070865	0.01504688	0.04100112	0	0	0.024
Iteration 5	3.8			Weight	0	0	0	0	0.5060183	0	0.49398169	0	0	
				Flow*Weight:	0	0	0	0	8.9368708	0	29.1751322	0	0	38.112
				Loss*Weight:	0	0	0	0	0.0035859	0	0.0202538	0	0	0.02384

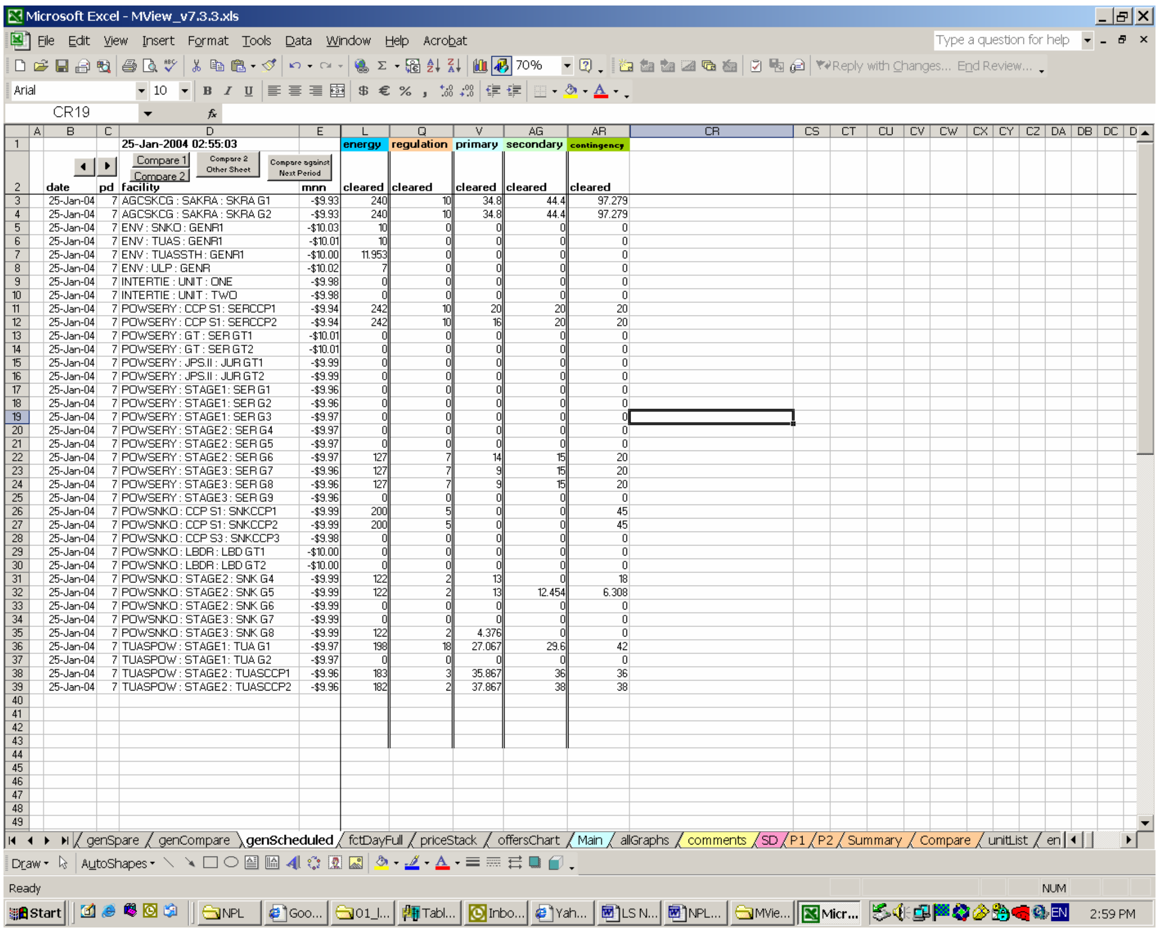
Though non-adjacent nodes are still presented in the solution, the iterations stopped because the SysError dropped below the threshold of 10MW.

3.2 An actual case in the NEMS

During the operation of the NEMS, cases of NPL occasionally occur. The most recent case occurred on 25 January 2004 when the USEP became negative from Period 5 to Period 10, as illustrated by the screenshot:



Taking Period 7 as an example, when the lowest price was observed, the dispatch results were as follows:

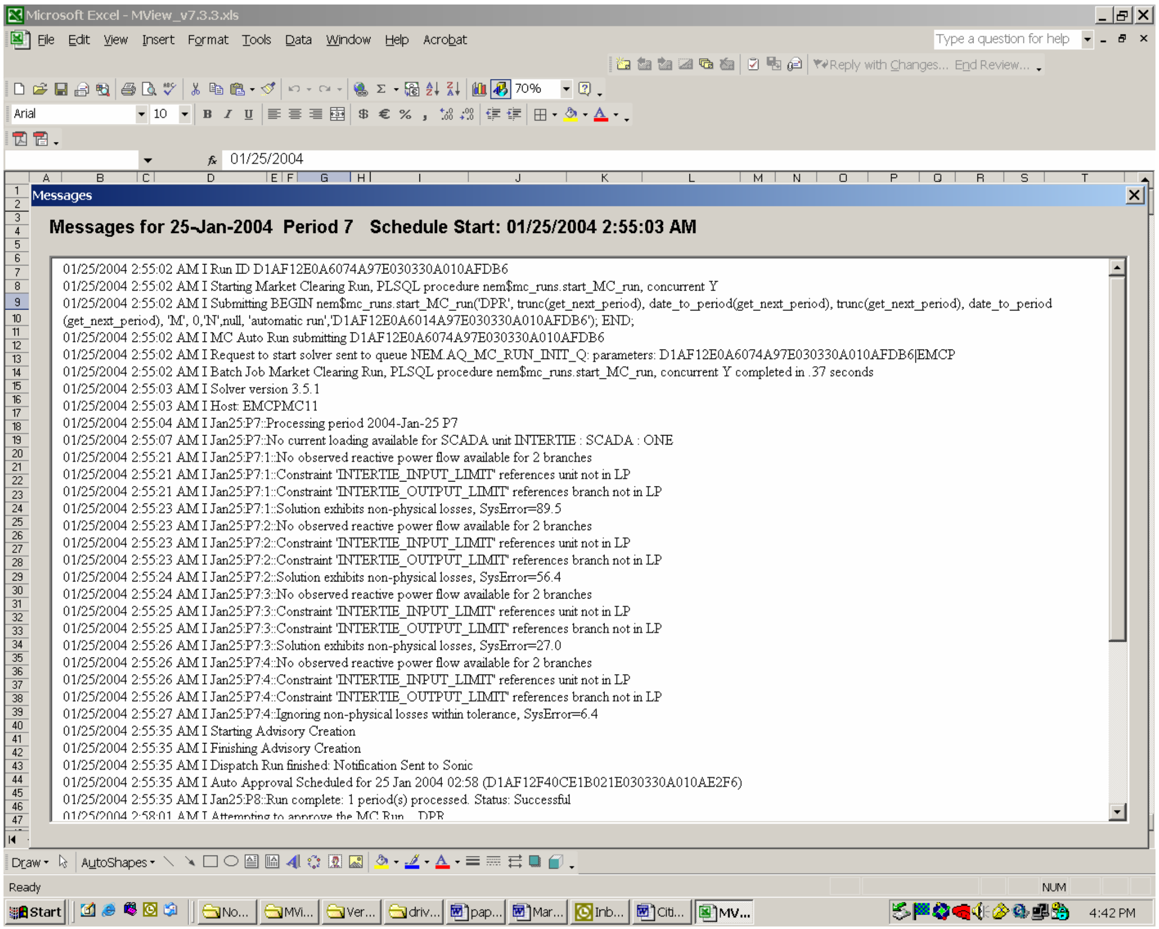


25-Jan-2004 02:55:03

date	pd	facility	mnn	energy cleared	regulation cleared	primary cleared	secondary cleared	contingency cleared
25-Jan-04	7	AGCSKCG : SAKRA : SKRA G1	-$9.93	240	10	34.8	44.4	97.279
25-Jan-04	7	AGCSKCG : SAKRA : SKRA G2	-$9.93	240	10	34.8	44.4	97.279
25-Jan-04	7	ENV : SNKO : GENR1	-$10.03	10	0	0	0	0
25-Jan-04	7	ENV : TUAS : GENR1	-$10.01	10	0	0	0	0
25-Jan-04	7	ENV : TUASSTH : GENR1	-$10.00	11.953	0	0	0	0
25-Jan-04	7	ENV : ULP : GENR	-$10.02	7	0	0	0	0
25-Jan-04	7	INTERTIE : UNIT : ONE	-$9.98	0	0	0	0	0
25-Jan-04	7	INTERTIE : UNIT : TWO	-$9.98	0	0	0	0	0
25-Jan-04	7	POWSERY : CCP S1 : SERCCP1	-$9.94	242	10	20	20	20
25-Jan-04	7	POWSERY : CCP S1 : SERCCP2	-$9.94	242	10	16	20	20
25-Jan-04	7	POWSERY : GT : SER GT1	-$10.01	0	0	0	0	0
25-Jan-04	7	POWSERY : GT : SER GT2	-$10.01	0	0	0	0	0
25-Jan-04	7	POWSERY : JPS.II : JUR GT1	-$9.99	0	0	0	0	0
25-Jan-04	7	POWSERY : JPS.II : JUR GT2	-$9.99	0	0	0	0	0
25-Jan-04	7	POWSERY : STAGE1 : SER G1	-$9.96	0	0	0	0	0
25-Jan-04	7	POWSERY : STAGE1 : SER G2	-$9.96	0	0	0	0	0
25-Jan-04	7	POWSERY : STAGE1 : SER G3	-$9.97	0	0	0	0	0
25-Jan-04	7	POWSERY : STAGE2 : SER G4	-$9.97	0	0	0	0	0
25-Jan-04	7	POWSERY : STAGE2 : SER G5	-$9.97	0	0	0	0	0
25-Jan-04	7	POWSERY : STAGE2 : SER G6	-$9.97	127	7	14	15	20
25-Jan-04	7	POWSERY : STAGE3 : SER G7	-$9.96	127	7	9	15	20
25-Jan-04	7	POWSERY : STAGE3 : SER G8	-$9.96	127	7	9	15	20
25-Jan-04	7	POWSERY : STAGE3 : SER G9	-$9.96	0	0	0	0	0
25-Jan-04	7	POWSNKO : CCP S1 : SNKCCP1	-$9.99	200	5	0	0	45
25-Jan-04	7	POWSNKO : CCP S1 : SNKCCP2	-$9.99	200	5	0	0	45
25-Jan-04	7	POWSNKO : CCP S3 : SNKCCP3	-$9.98	0	0	0	0	0
25-Jan-04	7	POWSNKO : LBDR : LBD GT1	-$10.00	0	0	0	0	0
25-Jan-04	7	POWSNKO : LBDR : LBD GT2	-$10.00	0	0	0	0	0
25-Jan-04	7	POWSNKO : STAGE2 : SNK G4	-$9.99	122	2	13	0	18
25-Jan-04	7	POWSNKO : STAGE2 : SNK G5	-$9.99	122	2	13	12.454	6.308
25-Jan-04	7	POWSNKO : STAGE2 : SNK G6	-$9.99	0	0	0	0	0
25-Jan-04	7	POWSNKO : STAGE3 : SNK G7	-$9.99	0	0	0	0	0
25-Jan-04	7	POWSNKO : STAGE3 : SNK G8	-$9.99	122	2	4.376	0	0
25-Jan-04	7	TUASPOW : STAGE1 : TUA G1	-$9.97	198	18	27.067	29.6	42
25-Jan-04	7	TUASPOW : STAGE1 : TUA G2	-$9.97	0	0	0	0	0
25-Jan-04	7	TUASPOW : STAGE2 : TUASCCP1	-$9.96	183	3	35.867	36	36
25-Jan-04	7	TUASPOW : STAGE2 : TUASCCP2	-$9.96	182	2	37.867	38	38

It was the unit ENV : TUASSTH : GENR1 that set the marginal price at (-$10/MWh).

The message log for this period said that NPL was observed and four iterations were conducted as a result.



The iterations stopped at the fourth round, because the SysError went below 10MW, which was the pre-defined threshold. Despite that, Period 7 was still observed to have the highest transmission loss on the day, due to the non physical loss.

3.3 Conclusion

With four iterations in this real-time dispatch run of the case study, the solver took about 33 seconds to complete. Compared with the 22 seconds taken by the DPR for Period 11 when only a single iteration was required, the performance of the solver was still comparable. Hence, there may be an incentive to further lower the threshold if NPL is triggered frequently.

4.0 Recommendation

With the current occurrence of NPL as 0.03% to date[3] (as of 31 July 2004), it is not cost effective to adjust the threshold value, taking into consideration the resources needed for User Acceptance Testing in both IT and Market Operations. However, should the NPL occurrence increase above 0.3%, i.e., to an average of once a week, it would trigger a proposal to update the SysError parameter so as to achieve a more accurate result.

[3] The occurrences of NPL since the market started on 1 January 2003:

- 3 January 2003, Period 10 ~ 11
- 25 January 2004, Period 5 ~ 10

Glossary

LP, linear programming

MCE, market clearing engine
The software used in the NEMS to discover dispatch schedule and prices.

NEMS, National Electricity Market of Singapore
The Singapore electricity market.

NPL, non-physical loss

Appendix A Market Rules

The Market Rules has a dedicated section for the handling of NPL, as extracted below:

Section D: Post-processing

D.22 Loss Calculation Correction

D.22.1 The procedure set out in this section D.22 shall be carried out whenever the conditions specified in section D.22.2 apply, except in the cases described in sections D.22.1 to D.22.13.

D.22.1.1 If the value of SysError calculated in accordance with section D.22.4 is less than the system loss error tolerance established by the *EMC* pursuant to section D.22.2, then the *EMC* may accept the current linear program solution and use the results for the *dispatch period* in the relevant *real-time dispatch schedule*, *short-term schedule, pre-dispatch schedule* or *market outlook scenario*.

D.22.1.2 If the number of repetitions of the procedures in this section D.22, in respect of a particular *dispatch period* and particular *real-time dispatch schedule* is equal to the maximum number of iterations for the loss calculation correction established by the *EMC* pursuant to section D.22.2, then the *EMC* may halt the process and the provisions of Chapter 5 section 9.1.2.2 and Chapter 6 section 9.3.2B shall apply.

Explanatory note: This is the case where the market clearing engine has failed to find a correct solution within the allotted time, and the incorrect solution is not good enough to send to the AGC system. Instead the PSO will manually dispatch the power system, and the prices will be calculated ex-post by the EMC, which will have more time for the MCE to run to an acceptable solution.

D.22.1.3 If the number of repetitions of the procedures in this section D.22, in respect of a particular *dispatch period* and particular *short-term schedule, pre-dispatch schedule* or *market outlook scenario*, is equal to the maximum number of iterations for the loss calculation correction established by the *EMC* pursuant to section D.22.2, then the *EMC* may accept the current linear program solution and use the results in the relevant *short-term schedule, pre-dispatch schedule* or *market outlook scenario*.

D.22.1.4 The *EMC* shall establish and *publish,* prior to the *market commencement date*, and may thereafter from time to time update and re-*publish* as required, values for the system loss error tolerance and maximum number of iterations for the loss calculation correction.

D.22.1.5 If any of the violation variables $\text{ExcessLineFlowForward}_k$, $\text{ExcessLineFlowReverse}_k$, $\text{DeficitLineFlowWeight}_k$, or $\text{ExcessLineFlowWeight}_k$ has a value greater than zero then the *EMC* need not carry out the procedures in this section D.22.

D.22.2 After each solution of the linear program specified in section C, the variables $\text{Weight}_{k,j}$ will be examined. Subject to section D.22.1, if the condition in section D.22.2.1 is false for any of the pairs of non-adjacent weights on a single *dispatch network line*, then sections D.22.3 to D.22.5 shall apply.

D.22.2.1 $\text{Weight}_{k,j} = 0$ or $\text{Weight}_{k,i} = 0$

$$\{k, j, i \mid j, i \in \text{DISCRSUB}_k, \text{where } k \in \text{LINES}, i > j+1\}$$

D.22.3 The total erroneous losses in the solution are calculated by the following formulae:

$$\text{ActualLoss}_k = \text{LineLossConst}_{k,i} + \frac{\text{LineFlow}_k - \text{LineFlowConst}_{k,i}}{\text{LineFlowConst}_{k,i+1} - \text{LineFlowConst}_{k,i}} \times (\text{LineLossConst}_{k,i+1} - \text{LineLossConst}_{k,i})$$

$$\text{CircuitError}_k = \text{LineLoss}_k - \text{ActualLoss}_k$$

$$\left\{ \begin{array}{l} i, k \mid i \in \text{DISCRSUB}_k, \text{where } k \in \text{LINES}, \\ i = \text{Max}\left(\begin{array}{l} j \mid j < N(DISCRSUB_k), \\ \text{LineFlowConst}_{k,j} \le \text{LineFlow}_k \end{array} \right) \end{array} \right\}$$

$$\text{SysError} = \sum_{k \in \text{LINES}} \text{CircuitError}_k$$

D.22.4 The set DISCRSUB_k shall be redefined for each line in the dispatch network. For each $k \in \text{LINES}$, the outer points of the line loss function in the forward and reverse directions shall be adjusted in the following manner:

D.22.4.1 Forward direction limit:

$$\{ i \mid i \in \text{DISCRSUB}_k, \text{where } k \in \text{LINES}, i = \text{Max}(j \mid \text{LineFlowConst}_{k,j} < \text{LineFlow}_k + \text{SysError}) \}$$

If *i* is the final point, then the forward direction limits shall not be adjusted,

Otherwise:

Discard $j \in \text{DISCRSUB}_k$ where $j > i$

Define new values:

$$\text{LineLossConst}_{k,i+1} =$$
$$\text{LineLossConst}_{k,i}$$
$$+\frac{\text{LineFlow}_{k} + \text{SysError} - \text{LineFlowConst}_{k,i}}{\text{LineFlowConst}_{k,i+1} - \text{LineFlowConst}_{k,i}}$$
$$\times\left(\text{LineLossConst}_{k,i+1} - \text{LineLossConst}_{k,i}\right)$$

$$\text{LineFlowConst}_{k,i+1} = \text{LineFlow}_{k} + \text{SysError}$$

where:

$\text{LineFlowConst}_{k,i+1}$ and $\text{LineLossConst}_{k,i+1}$, where they appear in the right hand side of the first equation, refer to values from the linear program that has just been solved, whereas the parameters on the left hand side of the two equations refer to new values of the these parameters.

D.22.4.2 Reversedirection limit:

$$\left\{ i \mid i \in \text{DISCRSUB}_{k}, \text{ where } k \in \text{LINES}, i = \text{Min}(j \mid \text{LineFlowConst}_{\text{k,j}} > \text{LineFlow}_{k} - \text{SysError}) \right\}$$

If *i* is the first point, then the reverse direction limits shall not be adjusted,

Otherwise:

Discard $j \in \text{DISCRSUB}_k$ where $j<i$

Define new values:

$$\text{LineLossConst}_{k,i-1} =$$
$$\text{LineLossConst}_{k,i}$$
$$+\frac{\text{LineFlow}_{k} - \text{SysError} - \text{LineFlowConst}_{k,i}}{\text{LineFlowConst}_{\text{k,i-1}} - \text{LineFlowConst}_{k,i}} -$$
$$\times\left(\text{LineLossConst}_{k,i-1} - \text{LineLossConst}_{k,i}\right)$$

$$\text{LineFlowConst}_{k,i-1} = \text{LineFlow}_{k} - \text{SysError}$$

where:

$\text{LineFlowConst}_{k,i-1}$ and $\text{LineLossConst}_{k,i-1}$, where they appear in the right hand side of the first equation, refer to values from the linear program that has just been solved, whereas the parameters on the left hand side of the two equations refer to new values of the these parameters.

D.22.5 Following the calculation of input data described in sections D.22.2 to D.22.4, the linear programme described in section C shall be resolved.