Tutorial 8: Actual Market Data

This tutorial looks at how to model a portion of the actual New Zealand electricity market, detailing where to locate the source files and how to extract the necessary modelling data. The results produced by the app are compared with those from the actual system.

We also use these sample models to further investigate transmission rentals, and to look at the impact that the ordering of the inputs has on the progress of the simplex algorithm.

Hawkes Bay Model

The portion of the New Zealand electricity market that will be modelled is the Hawkes Bay. The data is obtained from freely available online sources.

Source of real-world data

A diagram of the network model used by the New Zealand electricity market is available on the System Operator's website:

https://www.transpower.co.nz/system-operator/key-documents/maps-and-diagrams

The diagram is named the "Spd Locator drawing" so you can also find it using Google.

The input and output data for final pricing schedules from the New Zealand electricity market is available by going to the Electricity Authority (EA) website…

https://www.emi.ea.govt.nz/

…and then following the links: Wholesale Datasets, FinalPricing, CaseFiles.

Two sample models

The market data from the case files on the EA website has been used to build sample models that come pre-loaded with the app.

There are two versions of these samples. The larger of these more closely follows the actual market system, modelling the 110kV transmission system and the supply transformers that convert the voltage from 110kV to the distribution voltage of 33kV or 11kV. The load quantity is the value metered at the 33kV or 11kV buses. This model is referred to as the 033 model (because it models down to the 33kV/11kV level).

The smaller model uses the *scheduled* flow on the supply transformers to model the load at the 110kV level. This removes the need to model the supply transformers and makes the model faster to solve. It also allows us to account for the fixed losses of the supply transformers, which is something that the actual market solver includes but the app does not. This is referred to as the 110 model.

Loading a sample model

Sample models are loaded via the Models display, which is accessed via the Folder button indicated in Figure 100.

Figure 100: Button that leads to the Models display

Once on the Models display the Samples display is accessed via the Samples button located on the lower toolbar, as shown in Figure 101.

Figure 101: The Samples button on the lower toolbar of the Models display

The Samples display is shown in Figure 102. The sample models of the Hawkes Bay are the 033 model and the 110 model as described above.

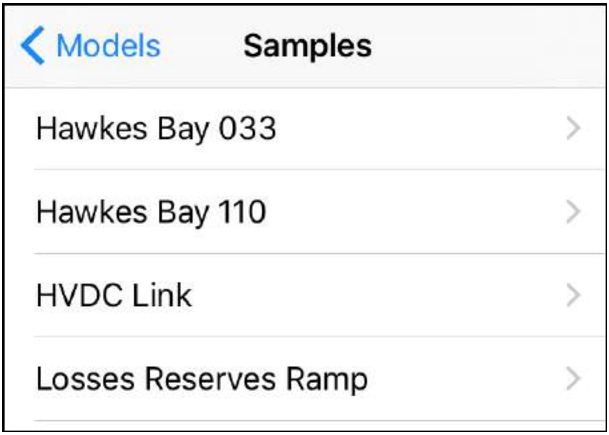


Figure 102: Samples display

View a screenshot of the 033 model by tapping its name, then set it as the current model by tapping the Load button on the toolbar. On an iPhone the model is larger than the display... you can zoom in and out using the pinch gesture. When the model is zoomed in you can move about (scroll) by dragging the background.

Real-world network model

The portion of the New Zealand electricity market that is modelled is shown in Figure 103. This is a section of the network model diagram from the System Operator's website, as described above.

The orange lines are 220kV, red lines are 110kV, green 33kV and black 11kV.

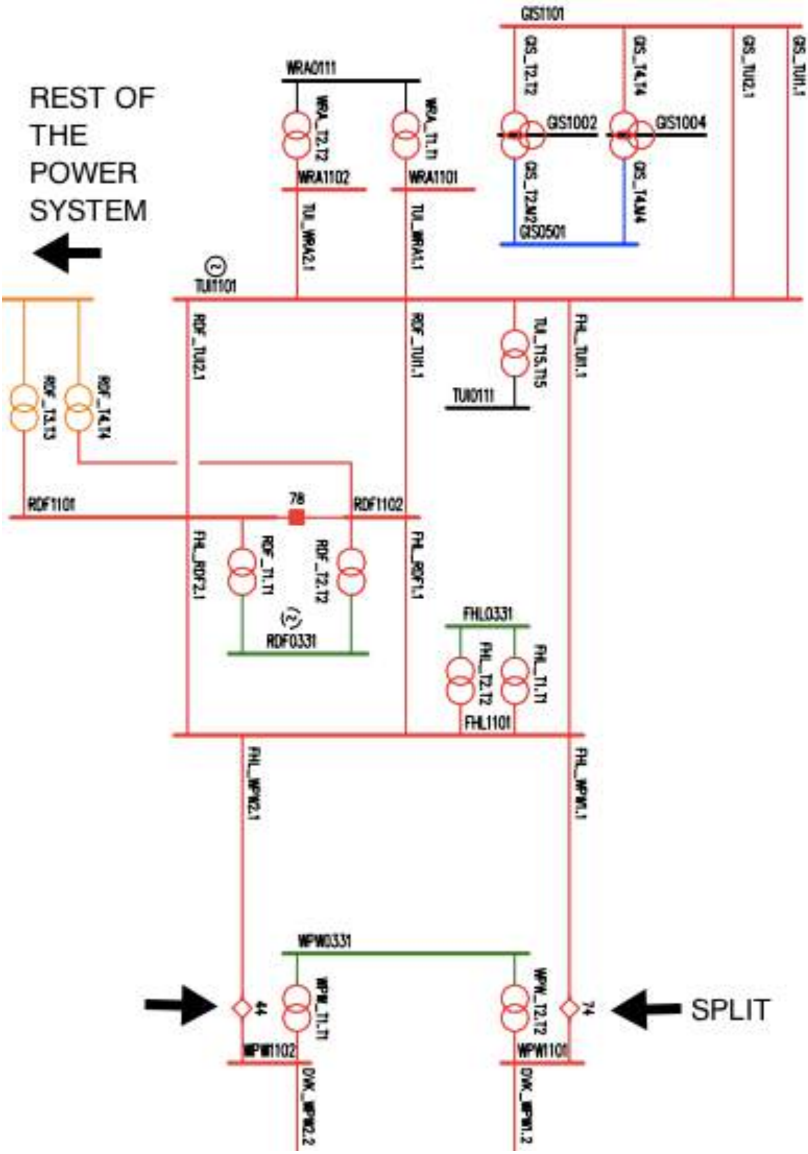


Figure 103: Hawkes Bay portion of the NZ electricity network

This portion of the electrical network covers the Hawkes Bay province of New Zealand. It connects to the rest of the power system via two interconnecting transformers, T3 and T4 at the Redcliffe (RDF) substation.

Modelling inflow from the rest of the system

In the sample models we use a dummy generator to model the inflow of power from the rest of the system via the T3 and T4 interconnecting transformers at RDF. The offer price and offer quantity of the dummy generator will be based on the real-world result at these interconnectors… the sum of the scheduled flow on T3 and T4 will be the offer quantity, while the offer price will be the bus price at the RDF 110kV bus.

There are transmission circuits to the south of the Hawkes Bay. These are capable of connecting to the rest of the electrical network, but they are not connected because there is an operational split in place to prevent overloads on the 110kV… the 110kV would effectively be in parallel with the 220kV if the split was closed.

Using real-world data

The sample models have been built using data from case files obtained from the Electricity Authority website, as described above.

The following sections describe how the case file data relates to the input data used by the app. There are some caveats. The first is that as of 01-April-15 the actual system moved from modelling branch losses using three flow-loss segments, i.e., three in each direction, to using six segments in each direction. The app is currently only set up to use three or four segments. Hence, while you can still use input data from after 01-April-15, there will be small differences in the results due to the differences in the number of segments.

The other caveat relates to the Hawkes Bay location. As of 01-April-15 (coincidentally the same date as the loss segments change) the substations at Gisborne (GIS) and Wairoa (WRA), which are both in the sample models, are no longer under the control of the System Operator, hence they have been removed from the electricity market model, and therefore you won't find their data in case files after this date.

Details of real-world data

The market data on the Electricity Authority website consists of zip files containing the 48 individual half hours (trading periods) that make up a trading day for the electricity market.

The date and time of the first period of the schedule are in the file name, e.g., for the file…

MSS_91112015011100714_0X

…the first period is 09-JAN-2015 11:00. Except, this is UTC time, so the local time is actually 10-JAN-2015 00:00. The schedule type is 111, which is a final pricing schedule. The 714 on the end is a random three-digit number.

Each zip file contains input files and result files for all of the trading periods covered by the case. For each trading period there is one results file and several input files. The data for the sample models is obtained from the input files shown in Table 4.

Table 4: Input file data to build a sample model

File extension	Section	Model data
PERIOD	BIDSANDOFFERS	ENOF = Energy offers
PERIOD	PNODEINT	MV90LOAD.

		Metered load at the supply bus. Used as load by the 033 model
MSSMOD	BRANCHLIMIT	Branch max flow
MSSNET	BRANCHBUS	Susceptance and Resistance

We also use data from the results file. As shown in Table 5 the results data is used to model the T3 and T4 interconnecting transformers as a dummy generator, and to provide the scheduled flow on the supply transformers, which we use as the load in the 110 model.

Table 5: Result file data used to build sample model

File extension	Section, Column	Model data
SPDSOLVED	BRANCH, TO_MW	Used as offer quantity for the dummy gen that represents the 220kV-110kV transformers T3 & T4
SPDSOLVED	BUS, PRICE	Used as offer price for the dummy gen that represents the 220kV-110kV

		transformers T3 & T4
SPDSOLVED	BRANCH, FROM_MW	Flow on the supply transformers, used as load by the 110 model

The above tables provide an overview of where the source data is located. The following sections show the details of how the data is extracted.

Generator offers

The energy offers for the actual generators (as opposed to the dummy generator that models T3 and T4) are from the BIDSANDOFFERS section of the PERIOD file, as shown in Figure 104.

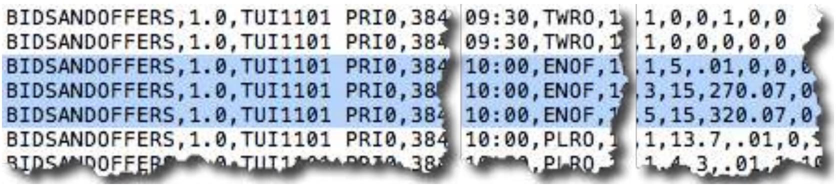

BIDSANDOFFERS,1.0,TUI1101 PRI0,384 09:30,TWRO,1 ,1,0,0,1,0,0
BIDSANDOFFERS,1.0,TUI1101 PRI0,384 09:30,TWRO,1 ,1,0,0,0,0,0
BIDSANDOFFERS,1.0,TUI1101 PRI0,384 10:00,ENOF,1 ,1,5,.01,0,0,
BIDSANDOFFERS,1.0,TUI1101 PRI0,38 10:00,ENOF,1 ,3,15,270.07,0
BIDSANDOFFERS,1.0,TUI1101 PRI0,384 10:00,ENOF,1 ,5,15,320.07,0
BIDSANDOFFERS,1.0,TUI1101 PRI0,384 10:00,PLRO,1 ,1,13.7,.01,0,

Figure 104: Energy offers from BIDSANDOFFERS section of PERIOD file, showing offers for generator PRI at the TUI bus

In-flow data

In our model the dummy generator named “T3&T4” at the RDF bus represents the in-flow of power from the rest of the power system to the Hawkes Bay area via interconnecting transformers T3 and T4.

The offer quantity for the dummy generator is the sum of the scheduled branch flows on the T3 and T4 branches. The offer price for the dummy generator is the scheduled bus price for the RDF 110kV bus. Note that the scheduled quantities are *results* from the actual system.

The scheduled branch flow is from the BRANCH section of the SPDSOLVED file as shown in Figure 105.

```
BRANCH,1.0,10-JAN-2015 10:00,QST  T3B T3B    0.000,  0.000
BRANCH,1.0,10-JAN-2015 10:00,RDF  T1  T1    20.738, 20.695
BRANCH,1.0,10-JAN-2015 10:00,RDF  T2  T2    20.133, 20.090,
BRANCH,1.0,10-JAN-2015 10:00,RDF  T3  T3    47.305, 47.187,
BRANCH,1.0,10-JAN-2015 10:00,RDF  T4  T4    47.305, 47.187
BRANCH,1.0,10-JAN-2015 10:00,RDF  RDF_TU    0.0000,  6.066
BRANCH,1.0,10-JAN-2015 10:00,RDF  RDF_TU    0.0000,  6.066
```

Figure 105: Scheduled branch flow from BRANCH section of SPDSOLVED file (used as offer quantity for dummy gen)

The scheduled bus price is from the BUS section of the SPDSOLVED file, as shown in Figure 106.

```
BUS,1.0,10-JAN-2015 10:00,333,GIS,100,     -0.1355,  78.2742
BUS,1.0,10-JAN-2015 10:00,334,GIS,110,     -0.1058,  78.2459
BUS,1.0,10-JAN-2015 10:00,335,RDF,33,      -0.0686,  74.9964
BUS,1.0,10-JAN-2015 10:00,336,RDF,110,     -0.0283,  74.9090
BUS,1.0,10-JAN-2015 10:00,337,RDF,220,      0.0195,  74.5919
BUS,1.0,10-JAN-2015 10:00,338,WRA,11,      -0.0857,  77.1013
BUS,1.0,10-JAN-2015 10:00,339,WRA,110,     -0.0567,  76.9490
BUS,1.0,10-JAN-2015 10:00,34,HEP,110       -0.0540,  76.1525
```

Figure 106: Scheduled bus price from BUS section of SPDSOLVED file (used as offer price for dummy gen)

Load data: from input data

For the 033 model the load data is from the MV90 column of the PNODEINT section of the PERIOD input file, as shown in Figure 107.

```
PNODEINT,1.0,WPW0331,10-JAN-2015 10:00,NR,0,0,0,16.731
PNODEINT,1.0,WRA0111,10-JAN-2015 10:00,NR,0,0,0,5.966,
PNODEINT,1.0,WRD0331,10-JAN-2015 10:00,NL,0,0,0,39.912
```

Figure 107: Load data from PNODEINT section of PERIOD file

Because we are obtaining our data from a Final Pricing schedule the load data represents metered load, i.e., load that was actually supplied. Hence, it is *required load* and therefore we will assign a very high bid price to ensure that it all clears.

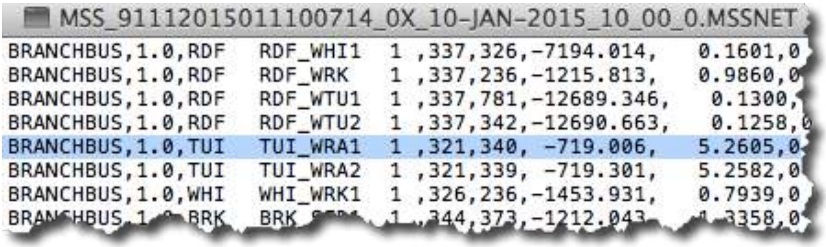
Branch data

The branch limit data is from the BRANCHLIMIT section of the MSSMOD input file, as shown in Figure 108.

```
BRANCHLIMIT,1.0,10-JAN-2015 10:00,TUI,T5,T5,XF,2000,0,2000,
BRANCHLIMIT,1.0,10-JAN-2015 10:00,TUI,T6,T6,XF,2000,0,2000,0
BRANCHLIMIT,1.0,10-JAN-2015 10:00,TUI,T7,T7,XF,2000,0,2000,0
BRANCHLIMIT,1.0,10-JAN-2015 10:00,TUI,TUI_WRA1,1,LN,36,0,36,
BRANCHLIMIT,1.0,10-JAN-2015 10:00,TUI,TUI_WRA2,1,LN,36,0,36,
BRANCHLIMIT,1.0,10-JAN-2015 10:00,TUK,TUK_TWH1,1,ZBR,2000,0,
BRANCHLIMIT,1.0,10-JAN-2015 10:00,TWC,BPE_TWC_LTN1,3,LN,210,
BRANCHLIMIT,1.0,10-JAN-2015 10:00,TWC,T1,T1,XF,2000,0,2000,
```

Figure 108: Branch limit from BRANCHLIMIT section of MSSMOD file

Branch susceptance and resistance are from the BRANCHBUS section of the period–specific MSSNET file, as shown in Figure 109.



```
MSS_91112015011100714_0X_10-JAN-2015_10_00_0.MSSNET
BRANCHBUS,1.0,RDF   RDF_WHI1  1 ,337,326,-7194.014,    0.1601,0
BRANCHBUS,1.0,RDF   RDF_WRK   1 ,337,236,-1215.813,    0.9860,0
BRANCHBUS,1.0,RDF   RDF_WTU1  1 ,337,781,-12689.346,    0.1300,
BRANCHBUS,1.0,RDF   RDF_WTU2  1 ,337,342,-12690.663,    0.1258,0
BRANCHBUS,1.0,TUI   TUI_WRA1  1 ,321,340, -719.006,    5.2605,0
BRANCHBUS,1.0,TUI   TUI_WRA2  1 ,321,339, -719.301,    5.2582,0
BRANCHBUS,1.0,WHI   WHI_WRK1  1 ,326,236,-1453.931,    0.7939,0
BRANCHBUS,1.0,BRK   BRK_      1 ,344,373,-1212.043     1.3358,0
```

Figure 109: Branch susceptance and resistance from BRANCHBUS section of period-specific MSSNET file

There is one of these period–specific MSSNET files for each trading period in the schedule, not to be confused with the single MSSNET file that covers all trading periods (we don't use data from that file because it mostly contains info about the connectivity of the network model… we manually built our model based on the System Operator's network diagram, so we don't need the model from the MSSNET file).

Per cent per-unit

In the New Zealand electricity market the resistance and susceptance values in the case files are per-cent per-unit, i.e., 100 times the per-unit value. Because the app expects per-unit values, the resistance and susceptance values from the input files must be divided by 100 to remove the per-cent factor before they are entered into the model.

Per-unit base

As discussed in the branch losses section, the app expects per-unit values that were calculated using a 100MVA base. The data in the input files was calculated using a 100MVA base, so we don't need to make any adjustments for that.

Result comparison

Figure 110 displays the result produced by the 033 sample model while Table 6 and Table 7 present the real-world results, extracted from the SPDSOLVED file.

Table 6: Bus results from SPDSOLVED file

ID_ST	ID_KV	LOAD	PRICE
FHL	33	32.995	75.7776
FHL	110	0	75.4302
GIS	50	25.791	78.3108
GIS	110	0	78.2459
GIS	11	0	78.2726
RDF	33	40.785	74.9964
RDF	110	0	74.909
TUI	11	0.291	76.8425
TUI	110	0	76.6103
WRA	11	5.966	77.1013
WRA	110	0	76.949

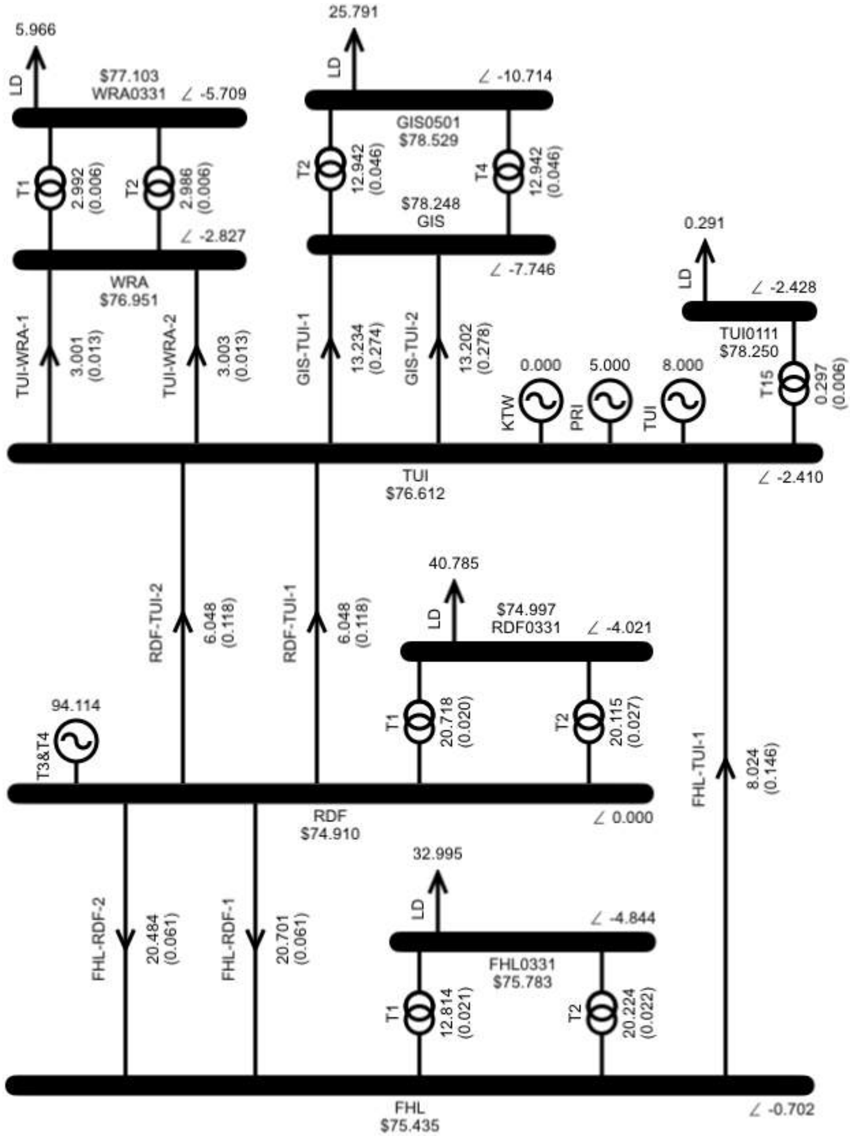


Figure 110: Result for Hawkes Bay 033 sample

Table 7: Branch results from SPDSOLVED file

BRANCHNAME	FIXED LOSS	FLOW	BRANCH LOSSES
FHL FHL_RDF1 1	0	-20.775	0.06202
FHL FHL_RDF2 1	0	-20.556	0.0609
FHL FHL_TUI1 1	0	8.056	0.14706
FHL T1 T1	0.0545	12.837	0.07543
FHL T2 T2	0.059	20.258	0.08147
GIS GIS_TUI1 1	0	-13.228	0.27438
GIS GIS_TUI2 1	0	-13.194	0.2779
GIS T2 T2	0.0286	12.92	0.03328
GIS T4 T4	0.0286	12.92	0.03328
RDF RDF_TUI1 1	0	6.066	0.11852
RDF RDF_TUI2 1	0	6.066	0.11852
RDF T1 T1	0.045	20.738	0.06541
RDF T2 T2	0.0326	20.133	0.05985
TUI T15 T15	0.0112	-0.297	0.0121
TUI TUI_WRA1 1	0	3.043	0.0134
TUI TUI_WRA2 1	0	3.037	0.01337
WRA T1 T1	0.0379	-3.01	0.0438
WRA T2 T2	0.0374	-3.005	0.04336

Differences between the app and the real-world results can be tracked down to the app not modelling fixed losses. Transformers have fixed losses, which are losses that occur when the transformer is energised, regardless of the flow. In the actual system the solver assigns the fixed losses 50-50 to the buses at each end of the transformer, regardless of where the dynamic losses are assigned. The app does not model fixed losses.

Simplifying the model and improving the results

As mentioned in the introduction, we can simplify the model by using the scheduled in-flow of the supply transformers as the load value. This will remove the need to model the supply transformers and the supply bus. It will also allow us to account for the transformer fixed losses… because the actual system assigns fixed losses 50/50 to the buses at either end of the transformer, half of the fixed losses are already included in the scheduled flow on the transformer. We can model the other half of the fixed loss value by explicitly adding it to the 110kV load.

Load data: from scheduled results

The scheduled in-flow on the supply transformers is obtained from the BRANCH section of the SPDSOLVED file as shown in Figure 111. The fixed loss is also obtained from the branch results.

```
BRANCH,1.0,10-JAN-2015 10:00,FHL FHL_RDF1   -20.713, -20.775,
BRANCH,1.0,10-JAN-2015 10:00,FHL FHL_RDF2   -20.495, -20.556,
BRANCH,1.0,10-JAN-2015 10:00,FHL T1  T1,     12.837,  12.789,
BRANCH,1.0,10-JAN-2015 10:00,FHL T2  T2,     20.258,  20.206,
BRANCH,1.0,10-JAN-2015 10:00,FHL FHL_TUI1     8.056,   7.909,
BRANCH,1.0,10-JAN-2015 10:00,FHL FHL_WPW1     0.000,   0.000,
```

Figure 111: Load from BRANCH section of SPDSOLVED file

For example, to calculate the 110kV load value for FHL, we add the branch flows on FHL T1 and T2. This flow will include half of the fixed losses that the actual solver assigned to the supply bus, the other half of the fixed losses are included in our model by explicitly adding them to the load value that we calculate from the transformer branch flows.

The scheduled flow and fixed losses for FHL T1 and T2 are shown in Table 7. Hence the value we use for the 110kV load at FHL is the scheduled flow plus half the fixed losses:

$$20.258 + 12.837 + (0.0545 + 0.059)/2 = 33.15175$$

The results of the 110kV model are shown in Figure 112. These results agree with those from the actual system to within 2 decimal places.

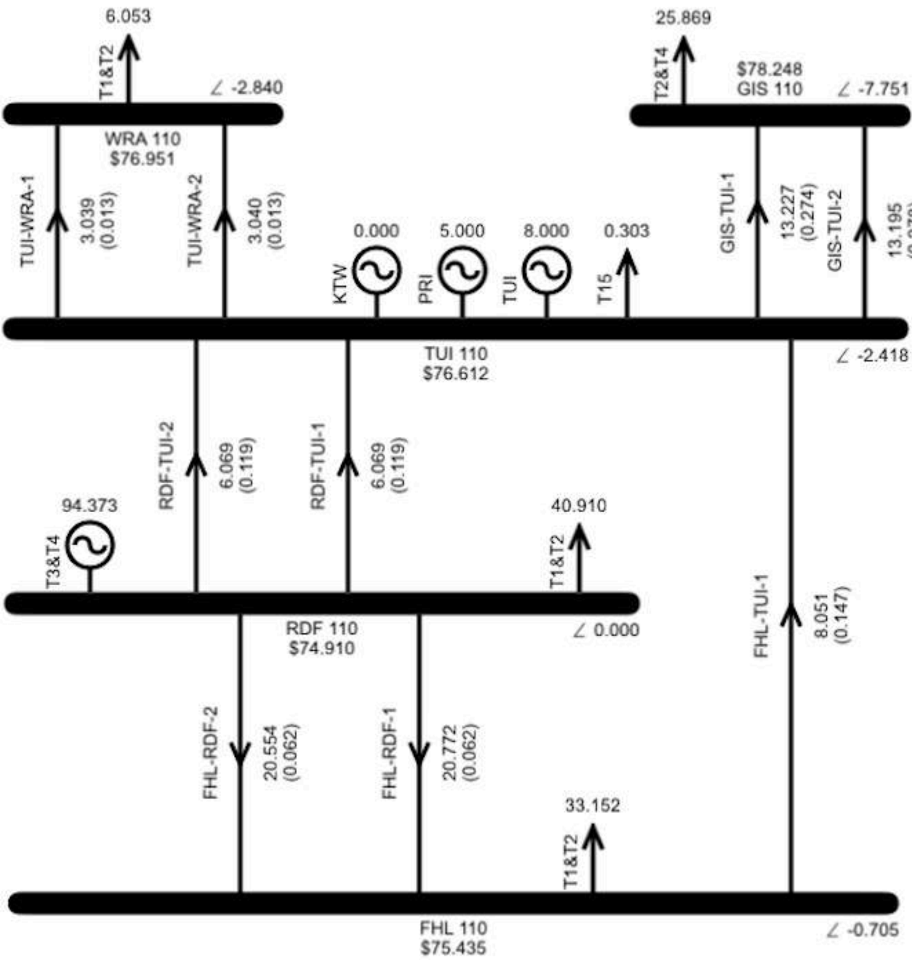


Figure 112: Result for Hawkes Bay 110 sample model

Further investigations

We can use the Hawkes Bay 110 model to conduct some further investigations as follows.

Changing the number of branch segments

Scroll through the loss results for the Hawkes Bay 110 result by using the forward and back arrows indicated in Figure 113. Notice that most of the scheduled branch flows are in the first flow-loss segment.

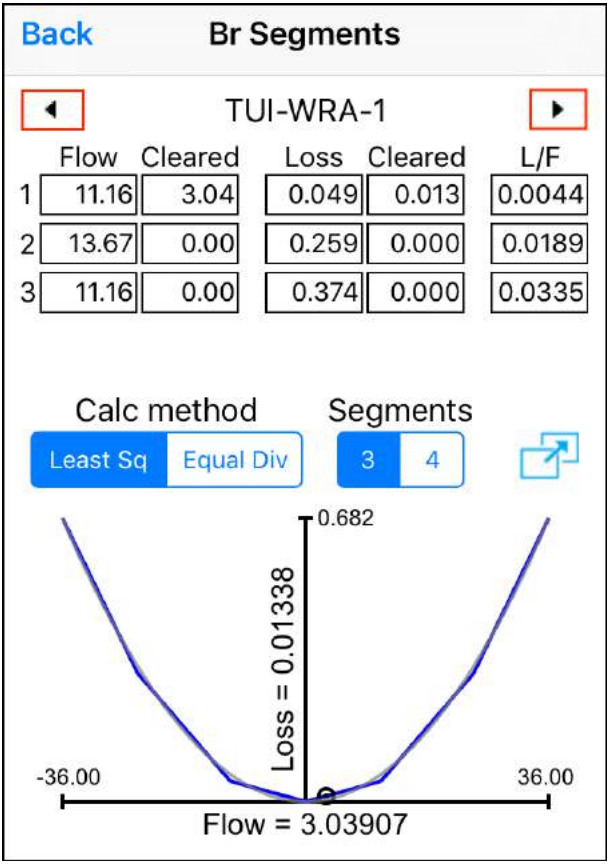


Figure 113: Use arrow buttons to scroll through loss results

As explained in Tutorial 4: Transmission Losses, it turns out that no loss rentals are incurred on branches where the scheduled flow is in the first flow-loss segment.

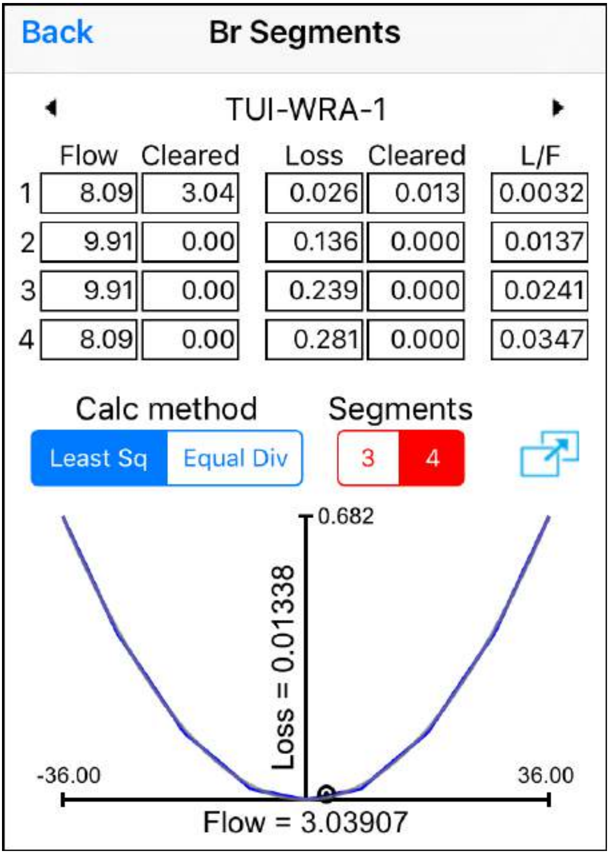


Figure 114: Changing number of segments from 3 to 4

If we increase the number of flow-loss segments from three to four then the flow on a number of the branches will move into the second flow-loss segment, and we can see what happens.

To change the number of branch segments from 3 to 4, go to the Losses display for any branch and tap the button for 4 segments. The button colour will change to red to indicate that the value has changed, as shown in Figure 190.

With the number of segments changed, when you leave the display you will be alerted that the change will be applied to all branches… tap OK to apply the change.

After solving the model with four branch segments, the Results display is shown in Figure 115. Now that fewer branches have flow confined to the first flow-loss segment there has been an increase in the transmission rentals, i.e., the $Grid on the Results display, for the reasons discussed in Tutorial 4: Transmission Losses.

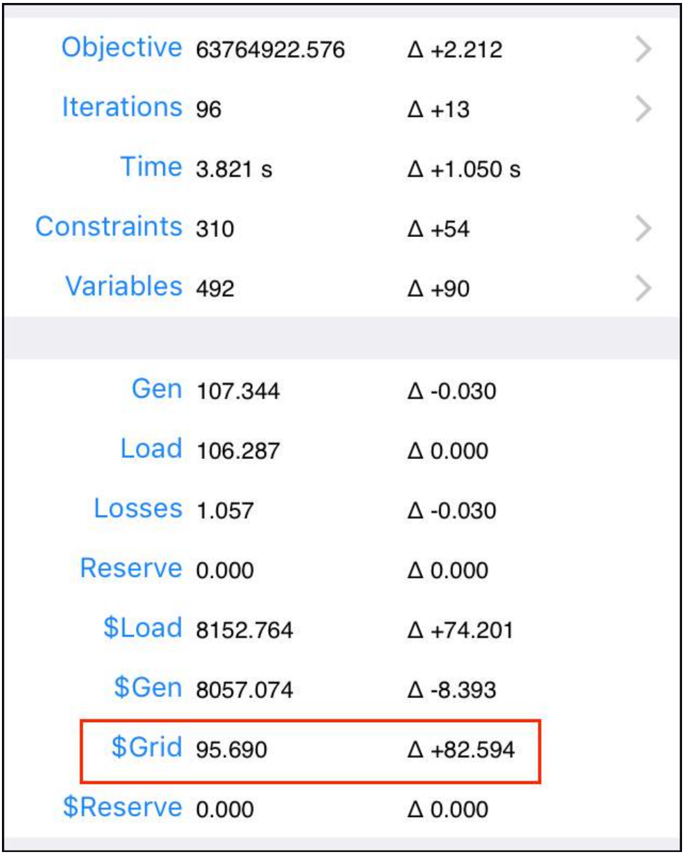


Figure 115: Result after increasing segments from 3 to 4

In contrast to the increase in transmission rentals, the losses have decreased slightly because the four-segment model has resulted in a lower loss estimate for the scheduled flows, due to the way that the segments have adjusted in the move from 3 to 4 segments.

Change the ordering of the constraints

Changing the order in which the components are supplied to the solver will change the order of the constraints in the initial tableau, and therefore change how the solve progresses.

Figure 116 indicates the Solve Setting that determines the sort order.

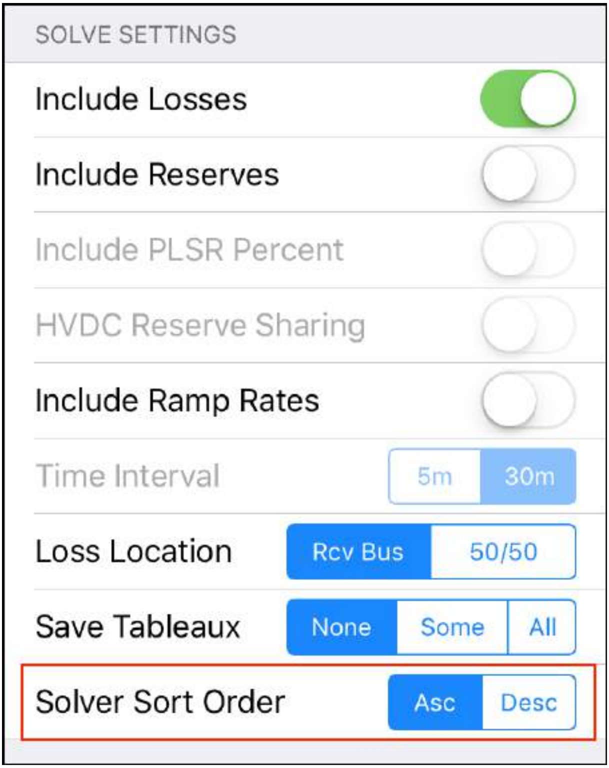


Figure 116: Changing the sort order of the constraints

Figure 117 and Figure 118 show the impact that different sort orders have on the progress of the simplex algorithm. These plots are accessed via Results – Iterations – Chart.

Note that although the path to the solution is different, the end result is the same. In Tutorial 9: Simplex Explained we will see why the sort order changes the path taken by the simplex algorithm.

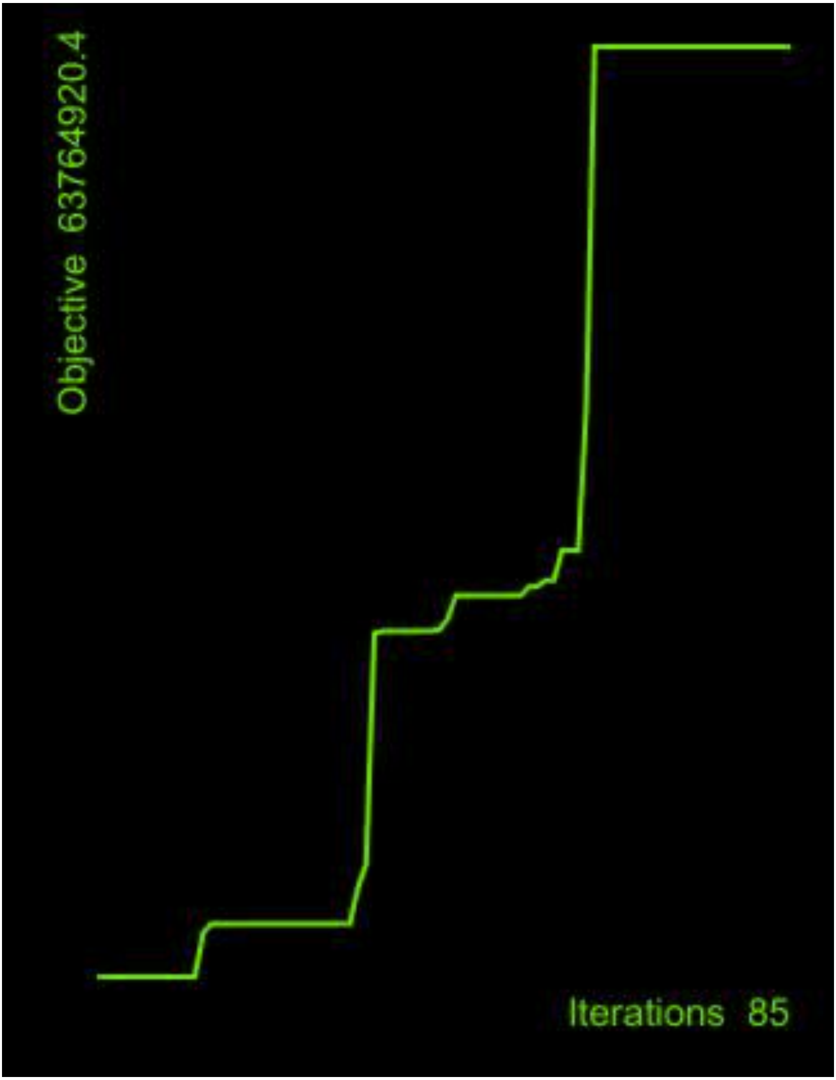


Figure 117: Objective value vs iteration count for the Hawkes Bay 110 model with ascending sort order

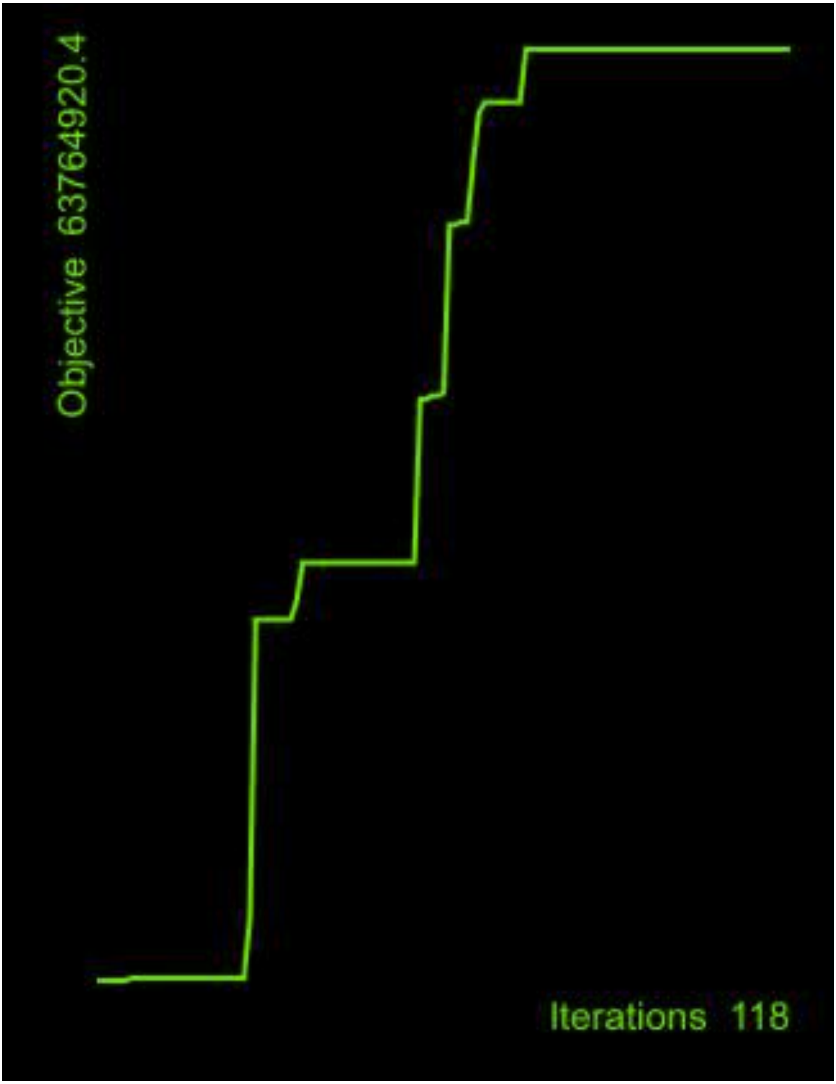


Figure 118: Objective value vs iteration count for the Hawkes Bay 110 model with descending sort order

Summary

In this tutorial we saw how to model a portion of the New Zealand electricity market by sourcing input data from the actual electricity market. The results produced by the app held up quite well when compared with the results from the actual market.

We used the sample model to investigate the impact that changing the number of branch segments has on transmission rentals, as explained in Tutorial 4: Transmission Losses.

We also investigated the impact that changing the sort order of the constraints has on the progress of the simplex algorithm. In the next section we will look at how the simplex algorithm solves the model, which will make it clear why the sort order has an impact.