

Appendix 6: Description of an example methodology and software for FTR grid design and determining FTR rentals

1. Introduction

The Authority has developed prototype software applications for the FTR manager functions of:

- FTR grid design; and
- determining the amount of the loss and constraint excess to be paid into the FTR account by the clearing manager (determining FTR rentals).

In this appendix the Authority provides a description of the methodology it has used to develop its prototype software applications for these functions. The Authority has released the source code for these prototype software applications on its website.

The Authority's intention in doing so is to:

- illustrate one potential methodology the Authority considers would be acceptable and relatively cost-effective;
- assist proposers to inform themselves of the inputs and calculations required for these FTR manager functions, thereby enabling proposers to cost the functions more accurately; and
- provide proposers with the option of basing their respective proposals on the algorithms implemented in the prototype software applications.

The Authority regards its methodology and prototype software applications for FTR grid design and determining FTR rentals as only one possible approach to developing these functions. Proposers are welcome to base their respective proposals on this approach or to develop an alternative.

The terms on which the Authority offers its prototype software applications to proposers for potential utilisation are:

- **Ownership:** The Authority will retain ownership of the rights, including intellectual property of the prototype software applications and any enhancements derived from them;
- **Further development, user acceptance testing, auditing:** The successful proposer (if using the Authority's prototype software applications) will develop further and finalise the prototype software applications, including conducting user acceptance testing, and auditing the system as per clause 3.17 of the Electricity Industry Participation Code (Code) prior to the system going live;
- **Maintenance and upgrades:** The successful proposer (if using the Authority's prototype software applications) will be responsible for maintenance and upgrades to the software, following the change control process described in the non-functional specification. Further, as set out in the system delivery agreement contracting principles, the system must be transferable to another party in the event of a future change to the provider for the FTR manager role; and

- The terms applicable to the ongoing use and support of the prototype software applications will be clarified during the Authority's contract negotiations with the successful proposer and reflected in the system delivery agreement.

2. Methodology for FTR grid design

Data inputs

1. **Forecast of configuration and capacity of the grid.** Under the Code, grid owners are required to provide a forecast of the configuration and capacity of their grids, including relevant planned outages, to the FTR manager (clause 13.251 of the Code). Transpower is the only grid owner captured by the Code provisions at present. The Authority's FTR grid design methodology assumes:

- there is a single forecast base grid for each FTR period covered by each FTR auction;
- the forecast base grids are provided in scheduling, pricing and dispatch (SPD) input file format; and
- the forecast base grids do not include information on security constraints.

2. **Outage data.** The Authority's FTR grid design methodology assumes outage data are available from the participant outage communication protocol (POCP) database (pocp.redspider.co.nz).

Applications

The Authority has used the following to create its prototype software application for the FTR grid design function:

- a Microsoft Access-based application to download and analyse POCP outage data. This application facilitates or automatically performs steps 1 through 6 in the following process; and
- a GAMS-based application "vSPD-FTR" with a Microsoft Excel user interface, which is a variant of the Authority's vSPD model.¹ This application performs security analysis on outage states to derive limits on the FTR grid. It performs step 8 in the following process.

Steps in the FTR grid design process

The process steps followed by the Authority in regard to the FTR grid design function are as follows (proposers are welcome to use, adapt, or enhance this process if they intend using it):

1. Download outage data from POCP for the relevant FTR period (automatic).
2. Check outage block names to see if they are mapped to valid SPD branch/device names (automatic).
3. Update the mapping table² using mappings from em6³ if possible; otherwise work out the mappings.

¹ vSPD means vectorised scheduling, pricing and dispatch. The vSPD model is the Authority's replica of the system operator's scheduling, pricing and dispatch (SPD) model.

4. Analyse outages to filter out those that are not relevant to (i.e. do not lie between) the current set of FTR hubs (initially these are the New Zealand electricity market's Benmore and Otahuhu nodes) (automatic).
5. Update the list of relevant and irrelevant outage block names with any new ones (manual).
6. Analyse outages to obtain a list of unique outage states that occur during the FTR period and that are relevant to (i.e. lie between) the current set of FTR hubs (automatic). An outage state may involve one or more overlapping outage blocks (or perhaps none) which result in a unique grid configuration. An outage state may occur several times within an FTR period.
7. Copy the list of unique outage states to the GAMS application (manual).
8. The GAMS application iterates through each outage state and each contingency from a pre-prepared list of contingencies that are relevant to (i.e. lie between) the current set of FTR hubs, and produces a list showing the maximum megawatts (MW) of FTRs that each outage-contingency combination will allow (automatic).
9. Apply the relevant rule(s). The simplest set of rules is to choose the outage-contingency combination which gives the lowest FTR MW limits. Other rules may involve some form of weighted average, or may ignore all outage states that have a duration of less than a defined threshold (for example, of less than 24 hours in the month). These rules are to be specified in the FTR allocation plan to be prepared by the FTR manager.
10. Scale back these FTR MW limits to allow for the risk of unplanned outages and, where relevant, to account for the cost of losses, and the impact of reserves constraints.⁴

Maintenance and development

Maintenance

The following maintenance tasks are associated with the FTR grid design process described above:

- maintain a mapping table between POCP outage block names and SPD branch/device names (step 3);
- maintain a list of relevant and irrelevant outage block names (step 5);
- maintain security constraint information. The FTR manager's model used in the FTR grid design process must include security constraints to be valid.⁵ Since security constraint data are available from the final pricing schedules and from associated input data produced

² Mapping table: Outages are designated in POCP by outage block names. Each outage block may involve the removal of one or more SPD branches or devices. It is necessary to maintain a table mapping outage block names to their associated SPD branch/device names, so that the outage block names can be interpreted and analysed correctly.

³ em6 is an Energy Market Services Ltd (EMS) application that provides reporting facilities for New Zealand electricity market data.

⁴ At times electricity flows between the Benmore and Otahuhu market nodes are constrained by the cost and/or availability of reserves to cover the HVDC link as a contingent event or extended contingent event.

⁵ The security constraints required are chiefly stability constraints. Thermal constraints are not required as they are handled by the contingency analysis process (step 8 of the example process).

by the pricing manager and published by the Authority,⁶ the FTR manager could estimate security constraints for forecast FTR grids based on current final pricing cases. However, because forecast FTR grids will generally be different for each future FTR period, the Authority considers that the FTR manager must, in addition, make judgements about what security constraints would be appropriate for future FTR periods and incorporate these into the forecast FTR grids; and

- if either of the two FTR hubs are changed to a different market node, update the hub location settings in vSPD-FTR.

Development

As noted in the main body of this RFP, the FTR market could in the future be expanded beyond two nodes. This section discusses how the Authority's prototype software application for FTR grid design could be developed to accommodate a change to the nature or number of FTR hubs.

At present each FTR hub is assumed to be a single market node. If the FTR hub definitions used for the FTR grid were changed to be a combination of market nodes (with still only two FTR hubs), this would require a minor change to the hub specification in vSPD-FTR.

If additional FTR hubs were added in a "linear" configuration (e.g. the Islington-Benmore-Haywards-Otahuhu market nodes) the basic prototype software application would still work. However, the prototype software application would require some enhancement to allow each link in the chain of FTR hubs to be analysed separately, thus enabling FTR MW limits to be calculated for each link. The FTR auction model⁷ developed by the FTR manager would also have to be enhanced to represent a multiple FTR hub linear grid model.

If additional FTR hubs were added resulting in a mesh (loop) configuration (e.g. the Haywards-Stratford-Otahuhu market nodes), it is less clear whether the Authority's FTR grid design prototype software application could be adapted to accommodate this.

Notes on the inputs and assumptions

The grid owner supplies a single forecast base grid for each FTR period covered by each FTR auction

For FTR periods well into the future (e.g. two years out), using a single forecast base grid for each FTR period is probably a reasonable assumption for at least two reasons. Firstly, even if grid changes are planned for partway through a month, the dates are unlikely to be firm. Secondly, for FTR periods well into the future, the full quantity of FTRs is unlikely to be offered upfront.

For FTR periods closer to the auction, grid forecasting becomes more critical and the assumption that the grid owner will supply a single forecast base grid for each FTR period is challenged (e.g. because a new transmission line is commissioned partway through a month). Therefore, the FTR manager's model will need to accommodate more than one forecast base grid for an FTR period,

⁶ The Authority intends to continue publishing this data, which is available at:
<http://www.ea.govt.nz/industry/monitoring/models-and-tools/vspd/input-files/>

⁷ The FTR auction model is a separate application that the FTR manager will supply to run the FTR auctions. The prototype process described here for FTR grid design assumes the FTR grid design is performed by a separate application to the auction model. The FTR grid design application would supply as an input to the auction model the number of FTRs that could be available for auction.

and be capable of deriving outage states that are a function of both multiple forecast base grid states and planned outages. Therefore, the FTR manager may need to request from the grid owner more than one forecast base grid for each FTR period (i.e. request forecast base grids that each cover part of an FTR period). As the Code does not specifically require the grid owner to provide this information, the grid owner's agreement to provide it will be necessary.

The forecast base grids are provided in SPD input file format

The format in which the forecast base grids are provided by the grid owner is subject to confirmation with the grid owner. If it is not in SPD format, the FTR manager could translate the grid data into SPD format.

The FTR manager should be aware that network models produced by the system operator for its SPD application have been pre-processed into a bus-branch model in which the status of network switches is usually not specifically represented. This means that if an outage specifies a change in the state of a network switch (rather than the switching out of a line for example), there may be insufficient information in a standard SPD bus-branch network model to model this outage. Therefore, if the FTR manager receives forecast base grids in SPD input file format, the FTR manager's requirements of the grid owner may include that the forecast base grid represents such switches as specific devices, including their state and connectivity.⁸ Alternatively, the FTR manager could itself maintain the details of such devices.

Outage data are available from pocp.redspider.co.nz

Currently, this database is populated by the grid owner approximately once each year, which means the forecast horizon varies throughout the year and may be sometimes insufficient for the FTR manager's purpose.

There are various ways to extend the forecast for outage data. One option is to perform an n-2 contingency analysis, which is equivalent to assuming that a planned outage could occur on any branch and then performing an n-1 contingency analysis. However, some actual outage states could be more severe than this, so this analysis could be optimistic. An offline analysis of all the actual grid states that have occurred over, for example, the last five years, could determine the lowest FTR MW limits over all of these states. This could become the default FTR grid where outage information is unavailable or unreliable.

3. Methodology for determining FTR rentals

Schedule 14.6 of the Code specifies the requirements for the calculation of FTR rentals.

Data inputs

- 1. Normal grid configuration model data** (i.e. the actual base grid with no outages and no contingencies), which must be supplied by the system operator. New data must be provided to the FTR manager by the system operator whenever the normal grid configuration changes, unless otherwise agreed with the FTR manager (clause 4 of schedule 14.6 of the Code).
- 2. Final pricing schedules and associated input data.** These data are published.

⁸ As the Code does not specifically provide for this, the grid owner's agreement to provide these will be required.

The methodology used by the Authority to develop its prototype software application for determining FTR rentals makes the following assumptions relating to the first data input:

- the system operator supplies normal grid configuration model data covering one or more entire billing periods (the Code defines a billing period to be one month);
- the system operator advises the FTR manager whether the current normal grid configuration model data are still valid and, if not, supplies new information;
- timing is approximately around the end of each billing period;
- normal grid configuration model data are provided in SPD input file format; and
- normal grid configuration model data may include voltage stability constraints and other similar constraints, although the Code does not mandate:
 - the provision of these constraints by the system operator; or
 - that the FTR manager must add these constraints if the system operator has not included them in the normal grid configuration model data.

Applications

The Authority has used the following to create its prototype software application for the function of determining FTR rentals:

- a MATLAB-based application which extracts price, grid configuration, branch loss, and constraint information from the final pricing schedule and associated input data files into csv files for uploading into a MySQL database; and
- MySQL database scripts.

Additionally, the Authority considers that a version of the prototype GAMS-based "vSPD-FTR" application used for the FTR grid design process could be modified to help support the function of determining FTR rentals, by undertaking the first two steps below.

The Authority considers its approach could be streamlined and anticipates that a proposer may package these processes into a single software application.

Steps in the process for determining FTR rentals

The process steps followed by the Authority in regard to the function of determining FTR rentals are as follows (proposers are welcome to use, adapt, or enhance this process if they intend using it):

1. Using a single base grid with no outages and no contingencies, determine the maximum MW of FTRs the grid can transfer in each direction. These maximum transfers are actually unbalanced MW pairs, where the MW arriving at the sink is less than the MW sent from the source, by an amount equal to the total network variable losses. This step implements clauses 5(1) through 5(3) of schedule 14.6 of the Code. This first step is similar to step 8 of the FTR grid design process. A modified version of the Authority's GAMS-based "vSPD-FTR" application could be developed to undertake this step.
2. Approximate each unbalanced MW transfer pair calculated in step 1 by a balanced MW transfer pair, in which branch flows are not less than those under the maximum unbalanced

MW transfer calculated in step 1. An approximate result can be achieved by simply increasing the received MW to equal the sent MW. Using the Authority's modified GAMS-based "vSPD-FTR" application referred to in step 1, the branch flows from this initial result can then be tested by rerunning step 1 with the MW transfer fixed at the maximum sent quantity calculated in step 1 and network losses and branch limits switched off. The MW transfer can then be adjusted iteratively until the branch flows are not less than those under the maximum unbalanced MW transfer calculated in step 1. This step implements clauses 5(4) and 5(5) of schedule 14.6 of the Code.

3. Using the MATLAB-based application described above, the shift factor matrix for each trading period can be produced for uploading into the MySQL database. These matrices require a large amount of storage, so it may be preferable to calculate them "on the fly". The calculation involves matrix inversion, which can be done efficiently in GAMS as well as in MATLAB. This step implements clause 6 of schedule 14.6 of the Code, with the exception of clause 6(3)(e). Implementing clause 6(3)(e) as required by the Code can be accommodated easily using the Authority's prototype software application for determining FTR rentals by storing the latest shift factor matrix for use as a backup version in case matrices for later trading periods are invalid.
4. The Authority's prototype software application requires manual uploads into the MySQL database of the shift factor matrices from step 3 as well as the other information extracted from the final pricing files by the MATLAB application. MySQL scripts are then used to implement clauses 7 through 9 of schedule 14.6 of the Code, except for the calculation of HVDC rentals and AC line (capacity) rentals.⁹ The Authority's prototype software application can be readily extended to do these, in order to meet the requirements of the Code.

Development

If the FTR hubs change or additional FTR hubs are added, then similar considerations would apply as for FTR grid design. However, although the Authority's prototype software application for FTR grid design may not accommodate a meshed hub configuration, the Authority's prototype software application for determining FTR rentals will definitely work for a meshed hub configuration, though the process will become more complicated than for a linear FTR hub configuration.

For a multiple FTR hub configuration, instead of FTR transfer pairs, the "FTR injection patterns" referred to in schedule 14.6 of the Code would need to be considered (i.e. the combination of positive or negative net FTR hub injections across the FTR grid). With two FTR hubs the task is to calculate the maximum flow from hub A to hub B and vice versa, which can be thought of as finding the ends of a line (1-dimensional shape). With three FTR hubs it is like searching for the corners of a polygon (2-dimensional shape, with each dimension representing the net MW injection at a different FTR hub). With four FTR hubs it is like searching for the corners of a polyhedron (3-dimensional shape), and so on. While the process is thus conceptually more complicated it should nevertheless be reasonably straightforward to automate.

⁹ The Authority's prototype software application also does not calculate mixed constraint rentals, as these do not currently exist.

Notes on the input data and assumptions

The system operator supplies normal grid configuration model data covering one or more entire billing periods

The normal grid configuration may sometimes change several times in a month and not necessarily at month boundaries. However, there may not be any material benefit in modelling the normal grid configuration to this level of precision. The Authority expects the FTR manager and the system operator to agree an appropriate frequency for updates to the normal grid configuration model data. Having a single normal grid configuration covering the entire billing period will simplify the FTR rental determination process.