Feasibility of Real-time Available Transfer Capacity Calculations with PSSE

Tamás Decsi, Dr. András Dán

Abstract

A new procedure is reviewed in this article that offers the possibility of the precision enhancement of intra-day network capacity calculations. The main advantages of the new procedure are the calculation capability of potential Emergency Assistance Service in reasonably short time and the enhancement of the intra-day trading activities.

Introduction

The role of the tie-lines that were built for emergency power exchange has changed by now. Nowadays, the main purpose of these interconnection lines has become to suffice and supply the more and more united international electricity market. Due to the scope of the transmission system operators' (TSO) duties, there is only limited possibility to influence flows that appear on their network, because these flows are basically formed by market actors. Currently, network models are provided by European TSOs in the frame of the Day Ahead Congestion Forecast (DACF) procedure to predict the probable flows, but the merging process of these models is time-consuming and not feasible all the time. Several flow forecasting methods were designed to avoid modelling difficulties. Since the forecasted flows don't give straightaway information about the available network capacity values, a new procedure was developed that is based on real-time measured data to predict border capacities.

Conception of Procedure

The new procedure is based on the following idea: if the network could be known at a given moment in the future, then capacity calculations could be carried out on the model that represents that moment. The N-1 criterion is only considered for the monitored part of the network during the calculations. During the examinations, the foreign TSOs' branches are considered only as elements that are probably going to be switched-off under contingency calculations because all the TSOs are responsible for their own network, thus the overloads on foreign lines are not limiting. Of course, the other TSOs do the same and the bilaterally agreed network capacity value is going to be the lower calculated one. The predicted network model is based on the network model of the TSO's EMS/SCADA[1] system and has the same level of detail, thus the real-time measured values and the current state of switching elements could be easily considered. The topology of the network model's part that represents the TSO controlled area is considered known because the switchings' and power plants' schedules and reasonable load forecasts are available. Switching schedules of the foreign parts are also available. There are available methods[2] for border flow forecasting, thus the border flows could be considered known, too. Network model could be generated by the usage of the aforementioned information that makes the capacity calculation achievable with sufficient precision.

Input Data of the Procedure

[1] **E**nergy **M**anagement **S**ystem / **S**upervisory **C**ontrol **A**nd **D**ata **A**cquisition
[2] These are described in papers [1],[2].

The presumptive generation pattern is adjusted with the data originated from the MAVIR NIP[3] system that contains the schedules of the power plants. The loads are adjusted with the load statistics of MAVIR's EMS/SCADA system. The topology is also known and could be set to the switching schedule given by the operation planning tool of HOSZ[4]. The switching plans for the foreign branches that affect the Hungarian grid are also available in the given schedule. The effects of international exchanges are predictable, thus could be treated as known due to the border flow forecasts such as the DACF-based PTDF calculation or the Neural network-based one.

Pragmatic Realization Possibility of the Procedure

The realization possibilities were verified via testing procedure. The testing timestamps were the mandatory timestamps of the DACF procedure, i.e. CET 03:30, 10:30, 12:30 and 19:30 for the period between 01.07.2010 and 31.10.2010. The Continental European models from the DACF procedure and the so called snapshot[5] models that originated from the SCADA system were available for these timestamps. These timestamps could act as reference points, because both the forecasted and actual flows are available for these timestamps. The actual flows were the objects of the approximations to avoid forecast errors during the tests that could cause the distortion in the results. The snapshot models that are generated two hours preceding the related timestamp and SPECTRUM[6] models made for the DACF procedure were used during the monitoring. The DACF models were used as references and the snapshot models were used for simulating the short-term border flow forecast. The target values for both the DACF and two-hour-preceding snapshot models were the flows that appeared on the borders in the actual snapshot for the investigated timestamps.
Hungarian cross-border flows were tried to be set as precisely as possible in the start-up models during the review. The setting was examined by a PYTHON script. PYTHON is a widely used scripting language that is used to script the PSSE load-flow program. The border flow settings were set by varying foreign generation and load pattern to approach the actual flows and the Hungarian were taken as firm due to the available schedules. The changes were realized by a short program which uses the PYTHON SCIPY module's "fmin_cg"[7] optimization function. The best results were given by the dispatch calculated with the following quadratic cost function minimization.
The cost function is defined by the following (1) equation.

$$COST = \underline{h}^T * \underline{h} + \underline{dX}^T * \underline{dX} * 0{,}01 + \underline{l}^T * \underline{l} \qquad (1)$$

where **h** is the vector of errors calculated on the tie-lines, **dX** is the load and generation deviation vector that is used to minimize and to smooth the changes. The machine limits are handled through the last element which is the **l** vector. The **l** vector's *i*th element is defined by following (2) relationship:

$$l_i = \frac{\left(X_i - 0.5 * P_{\max.i} + 0.5 * P_{\min.i}\right)^2}{4 * \left(P_{\max.i} - P_{\min.i}\right)^2} \qquad (2)$$

[3] IT system that supports market handling and maintanance. (**Ny**I**tott** **P**iac in hungarian means opened market)
[4] **H**álózati **O**peratív **Sz**olgálat – Network Planning Operation Service
[5] Network model based on real-time state estimation which is generated by SPECTRUM with approximately 5 minute cycle.
[6] The EMS/SCADA system of MAVIR.
[7] The function is based on the Polak-Ribière conjugate gradient algorithm. [3]

where Xi is the active power output of the *i*th machine, $P_{max.i}$ is the technical maximum $P_{min.i}$ is the technical minimum for machine i. The values that appear in the cost function are calculated from simplified DC load-flow results.

In sequence, the elements of the cost function were used to minimize the approximation errors (**h**), to improve the convergence capability of the models (**dX**) and to ensure a plausible generation-pattern (**l**).

The exploration of the border flow setting tests yielded the statistics that can be seen on the two figures (Fig. 1 and Fig.2) below.

In the first case, the setting success that was reached by changing the Hungarian generation-pattern and the foreign load-pattern is shown in Fig. 1.

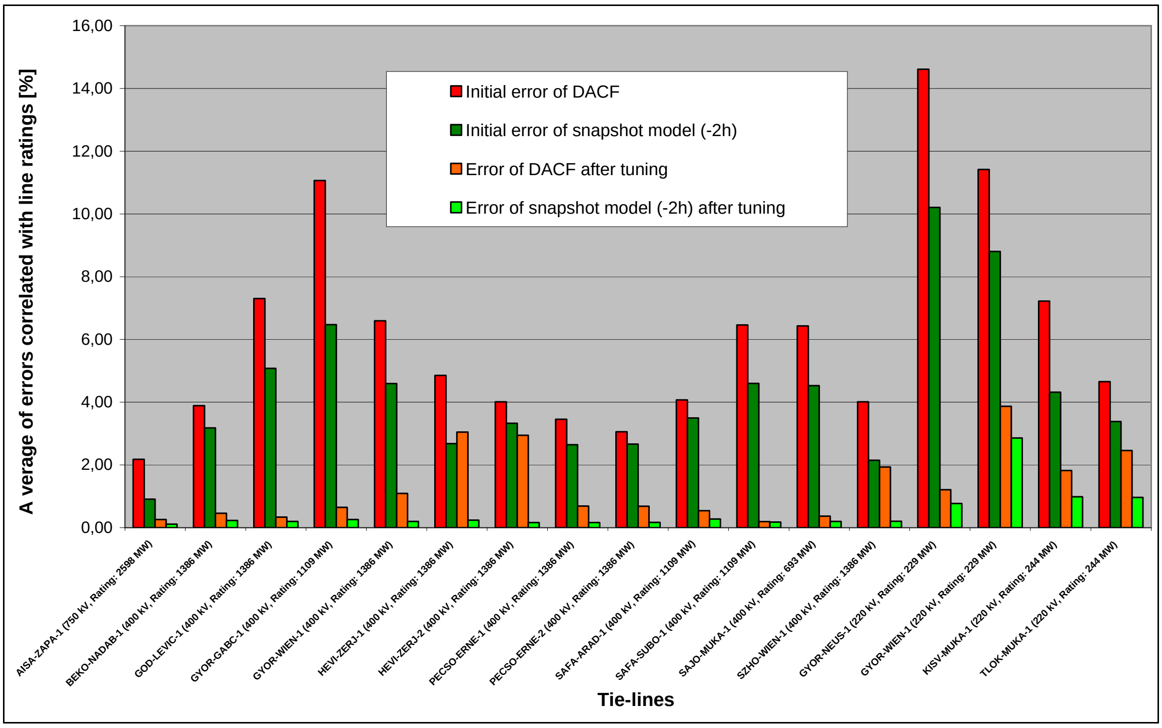

Figure 1. – Tuning by load-pattern modification

Based on the shown results, it can be stated that the tuning was successful in decreasing approximation errors on all of the tie-lines. The approximation errors in the tuned models are less then 4% for each tie-line. In case of snapshot models, only one tie line has an average approximation error that is greater then 1%.

In the second case, the foreign generation-pattern was modified instead of the load-pattern. In this case, the tuning redounded to the statistics that can be seen on figure 2. Comparing the statistics of Figure 2 and Figure 1, it can be asserted that the second solution yields less precise approximation. The decrease in precision can be explained by the fact that there are only few generation busbars as compared to the number of busbars that have a load. The protuberant values are linked to 220 kV lines. The reason of these values can be found in the network topology representation. Each of the Wien – Győr, Neusiedl – Győr and Tiszalök – Mukacevo, Kisvárda - Mukacevo tie-lines are part of double-circuit lines together with the Neusiedel – Wien and Sjószöged – Tiszalök, Sajószöged – Kisvárda line sections. There is no generation busbar among these tie-lines, thus their flow can be adjusted collectively if only the generation pattern is changed. The signed errors got during the tests confirmed this statement.

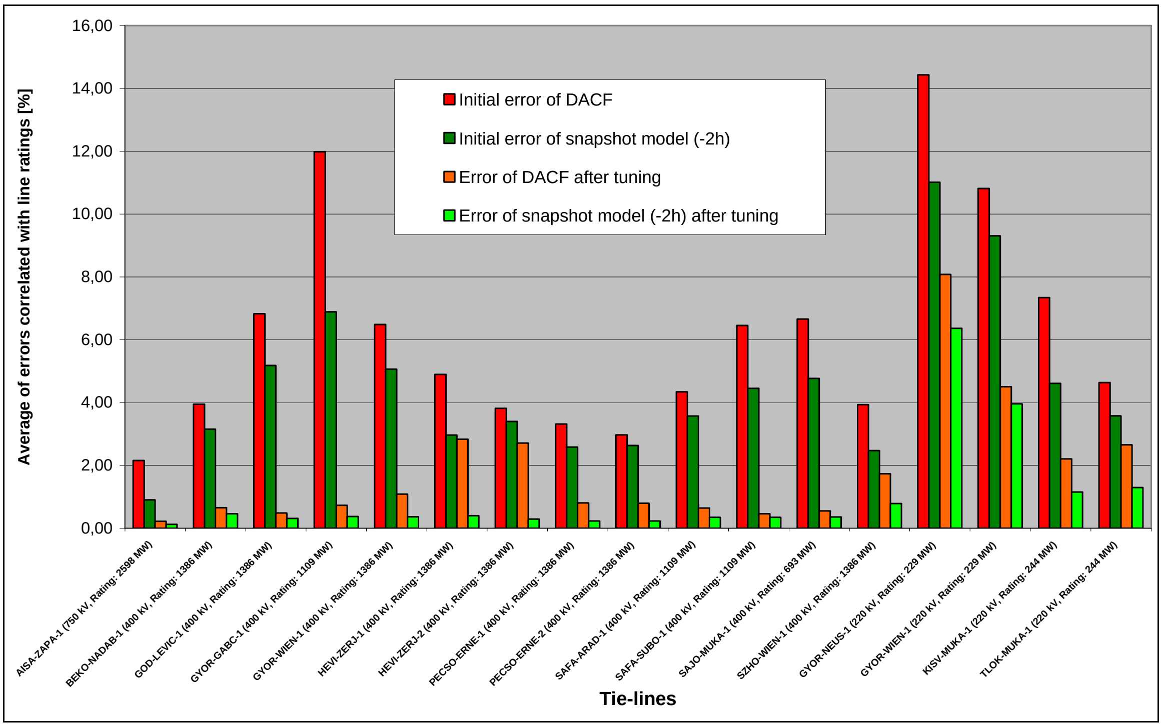

Figure 2. – Tuning by generation-pattern modification

Assessment

If the data mentioned among the input data of the procedure exists, the following can be stated based on outcome of the test: a network model could be generated with the help of the intra-day borderflow forecast algorithm which is adequate for cross-border capacity calculations.

The first part of the statement is demonstrated by the test results. The adequacy is proven by the fact that the TSOs have detailed and accurate information about their control area. The controlled area's approximated state could be simulated with this information and the foreign area tuning based on borderflow forecasts gives good boundary conditions for the network model. The accurate foreign base case load and generation pattern doesn't affect the calculated capacities significantly if the topology of the foreign network is correct, which is supported by real-time international measurements. The reason why the capacity is not affected significantly is the fact the capacities are calculated with the linear TLTG[8] method by MAVIR. The calculation is based on PTDF[9] and OTDF[10] factors and on proportional redispatch among the machines controlled by their nominal power, thus the calculation is sensible only for the boundary conditions (border flows) and for the network elements' state. The model generated by the aforementioned procedure is suitable for AC calculations which is a great effort, as emergency state system conditions such as voltage collapse could be considered during calculations.

Finally, we can state that adequate intra-day capacity calculations have become possible by the usage of intra-day borderflow forecasting, even in derangement conditions. These calculations made the fast and precise calculation of possible Emergency Assistant Service value considering the N-1 principle available.

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[8] **T**ransfer **L**imit **T**able **G**eneration
[9] **P**ower **T**ransfer **D**istribution **F**actor
[10] **O**utage **T**ransfer **D**istribution **F**actor

Glossary

[1] Lajos Oroszki, László Bürger, Péter Gölöncsér, Tamás Decsi, Géza Sebestyén: Various Methods for Forecasting Cross-border Power Flows in the Hungarian Transmission System (C2-202), Cigre Session 2008, 2008. August 24-29., Paris

[2] Tamás Decsi - Dr. András Dán: State of the Art of the Hungarian Cross-border Power-Flow Forecasting, 2008, Vol. 9. p. 5-7, Budapest

[3] Jorge Nocedal, Stephen J. Wright: Numerical Optimization, 1999, p. 120-122.