PSERC 98-05

Alternatives for calculating Transmission Reliability Margin (TRM) in Available Transfer Capability (ATC)

Peter W. Sauer

Copyright 1998 IEEE. Published in the Proceedings of the Hawaii International Conference on System Sciences, January 6-9, 1998. Kona, Hawaii.

Alternatives for calculating Transmission Reliability Margin (TRM) in Available Transfer Capability (ATC)

Peter W. Sauer
Department of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign
Urbana, IL
sauer@ece.uiuc.edu

Abstract

There is very little theory developed for the calculation of the Transmission Reliability Margin (TRM) in the Available Transfer Capability (ATC) computation of electric power systems. This paper proposes and evaluates several different approaches to the calculation of TRM. The TRM is supposed to account for uncertainty in the operating conditions used in computing Total Transfer Capability (TTC). This uncertainty may be in model parameters (line impedances), load forecast error (P and Q), or other ìbase caseî data.

1. Introduction

The movement towards open-access transmission and associated Federal rulings have added considerable emphasis to the interest in quantifying electric power system transmission capabilities. This interest has led to new definitions and recommended methods of determination by NERC [1]. The "Transmission Reliability Margin (TRM)" is the amount of transmission capability necessary to ensure that the interconnected network is secure under a reasonable range of uncertainties in system conditions. The "Capacity Benefit Margin (CBM)" is the amount of transmission transfer capability reserved by load serving entities to ensure access to generation from interconnected systems to meet generation reliability requirements. With these two terms added, "Available Transfer Capability (ATC)" is equal to:

$$ATC = TTC - TRM - ETC - CBM$$

where TTC is the Total Transfer Capability between two points, and ETC is the sum of "Existing Transmission Commitments (which includes retail customers)" between those same two points.

Several approaches to the computation of TRM have been proposed [2]. One is based on repeated computation of TTC using variations in the base case data. This is a brute force, "Monte Carlo" statistical approach. A second is a single repeat computation of the TTC using limitations reduced by a fixed percentage (i.e. 4%). A third is simply to reduce the TTC by a fixed percentage (i.e. 5%). These last two would normally result in a lowering of ATC. A fourth is a probabilistic approach using statistical forecast error and other systematic reliability concepts.

The objective of this paper is to explore the various options for computing TRM. This includes a comparison of the above alternative methods

2. The Study System

A three-area system was used to explore the various options for computing TRM. Each area consists of a single bus with generation and load. Each area is connected by a single line. The areas were numbered 1, 2, and 3. The base case data for the system was:

Base power is 100 MVA.

Bus 1 was the swing bus with 1500 MW load
Bus 2 had 600 MW generation and 600 MW load
Bus 3 had 800 MW generation and 800 MW load

Bus 1 had a voltage set point of 1.00 pu
Bus 2 had a voltage set point of 1.00 pu
Bus 3 had a voltage set point of 1.04 pu

All line resistances were zero.
Line 1-2 had a reactance of 0.90 pu
Line 1-3 had a reactance of 0.37 pu
Line 3-2 had a reactance of 0.28 pu

Line 1-2 had a rating of 100 MVA
Line 1-3 had a rating of 130 MVA
Line 3-2 had a rating of 140 MVA

3. Maximum Transfer 1-2

The transfer under study was from bus 1 to bus 2. This was implemented by a decrease in generation at bus 2, with the real power being supplied automatically by the swing generator at bus 1.

The base case had zero real power flow on all lines. When the generation at bus 2 was decreased by 10 MW (causing a 10 MW transfer from 1 to 2), the real power flow on the lines became:

P1-2 = 4 MW
P1-3 = 6 MW
P3-2 = 6 MW

These flows provide the real-power distribution factors for each line as 40% on 1-2, 60% on 1-3, and 60% on 3-2.

From the ratings of the lines, extrapolation of the transfer using real power distribution factors to the line limits gave three transfer limits:

Limiting line 1-2: 100/0.4 = 250 MW transfer 1 to 2
Limiting line 1-3: 130/0.6 = 217 MW transfer 1 to 2
Limiting line 3-2: 140/0.6 = 233 MW transfer 1 to 2

The smallest of these was 217, making this the linear estimate of the Total Transfer Capability (TTC) from bus 1 to bus 2. When the generation at bus 2 was decreased to simulate the transfer, a decrease of 203 MW brought line 1-3 to its 130 MVA limit. This means that the actual nonlinear (and VARS considered) TTC under these conditions was 203 MW rather than the predicted 217 MW. This +7% error is due to two things. First, the prediction assumed linear flow distribution. Second, the prediction was based only on

MW flows. This implies that a TRM of up to 7% may be justified because of these modeling/computational errors.

4. Error in Line Reactance

To investigate uncertainty in the data, consider the reactance of the lines. A 10% increase in the line 1-3 reactance from 0.37 to 0.407 increased the TTC to 206 MW (1.5% increase), while a 10% decrease in that reactance from 0.37 to 0.333 decreased the TTC to 200 MW (1.5% decrease).

A 10% increase in the line 1-2 reactance from 0.90 to 0.99 decreased the TTC to 196 MW (3.4% decrease), while a 10% decrease in the line 1-2 reactance from 0.9 to 0.81 resulted in a TTC of 212 MW (4.4% increase).

A 10% increase in the line 2-3 reactance from 0.28 to 0.308 increased the TTC to 206 MW (1.5% increase), while a 10% decrease in the line 2-3 reactance from 0.28 to 0.252 resulted in a TTC of 200 MW (1.5% decrease). Taking the worst case, this means that a TRM of up to 3.4% may be justified to account for these data errors.

It may be possible to analytically predict this by examining the impact of 10% error on the analytical expression for the real-power distribution factors [3]. Or, to formulate the sensitivities of the distribution factors to small changes in line impedance. Recomputing the distribution factors more accurately (2 decimal places) showed that the base case reactances gave distributions of 0.41 and 0.59 (rather than the roundoff factors of 0.4 and 0.6). When the reactance of line 1-2 was increased by 10%, the factors changed to 0.387 (5% decrease) and 0.613 (4% increase). This 4% increase in the 1-2 distribution factor would have predicted a TTC of 212 MW (130/0.613) rather than the 220 MW (130/0.59) which would be predicted by the two-decimal original factor 0.59. This is very close to the 3.4% reduction in TTC actually observed with a 10% increase in the line 1-2 reactance. This implies that it may be useful to further investigate analytical sensitivities of distribution factors to small changes in reactances for the purpose of computing a TRM component to account for model error.

5. Reduction In Line Ratings

When the above TTC was computed using a 3% reduction in all line ratings, the TTC was found to be 197 MW (3.0% decrease). This implies that there is a very close correlation between reduction of line ratings and reduction of TTC. This heuristic approach needs to be investigated further to establish a stronger theoretical basis for use as a TRM component.

6. A Probabilistic Approach

Most viable probabilistic approaches to uncertainties in parameters rely on linear approximations and zero-mean Normal distributions. With this, the mean value of most quantity deviations remains at zero ñ providing little improvement in expectations. The computed variance does however provide an indication of a likely range of values for the deviation. If TRM is to be a ìreduction onlyî concept, then something like 3 standard deviations from Normal might be a viable approach to computing a component of TRM.

7. Acknowledgements

This work was supported in part by funds from National Science Foundation Grant NSF EEC 96-15792, the University of Illinois Power Affiliates Program, the Grainger endowments to the University of Illinois, and Power Engineering Engineering Research Center (PSERC) subcontracts from Cornell University.

8. References

[1] Transmission Transfer Capability Task Force, "Available Transfer Capability Definitions and Determination", North American Electric Reliability Council, Princeton, New Jersey, June 1996.

[2] P. W. Sauer, "Technical Challenges of Computing Available Transfer Capability (ATC) in Electric Power Systems", Proceedings of the Thirtieth Annual (1997) Hawaii International Conference on System Sciences, Vol V, pp. 589-593.

[3] P. W. Sauer, "On the Formulation of Power Distribution Factors for Linear Load Flow Methods,î IEEE Transactions on Power Apparatus and Systems, Vol. PAS-100, No. 2, February 1981, pp. 764-770.