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## Selection of Lines to be Switched to Eliminate Overloaded Lines Using a Z-Matrix Method

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**Summary**

There are many ways in which a system can be adjusted to compensate for an overloaded line. Earlier studies have shown that shifts in generation or phase shifter adjustments can be calculated to correct an overload. These corrections are based on an analytical solution of the system. Many algorithms have been developed to use these techniques in optimal power flow solutions. Generation schedules are based on economic dispatch and any deviation from the proper schedule to eliminate overloads will result in an increase in production costs.

There have been a considerable number of papers in the literature that have presented methods of solving large problems, such as the power system load flow problem, using different approaches with a large amount of numbers in storage and more computer time. Methods have been developed to identify overloaded lines and to select one or more lines to be removed in order to reduce the overload in a power system.

Recent research in reference [1] indicated that a simple method of redirecting power flow to reduce the overload in a line is to selectively switch the network. A line can be added to or removed from the system in order to cause a shift in the power flow and to eliminate the overload. The selection of a line to be switched is a complicated process. The addition or removal of a line must not cause any other overloads on the system as it eliminates the original overload. Also, a system should be developed to identify the possible combinations of lines to be switched and to rank them in order of effectiveness.

To determine the power flow in a line during a contingency evaluation, it is not practical or economic to run a load flow study for each evaluation. This wastes valuable computer time since it calculates the power flow in every line. For the purposes of contingency evaluation, only a few lines are of interest: the critical lines, which cause overloading in other lines when opened, and the limiting lines, which tend to become overloaded. Therefore, using a Z-matrix evaluation technique, only the axes of the lines of interest must be saved; all other axes can be discarded as soon as possible to avoid using unnecessary computer memory space.

The goal of this paper is to prove that a Z-matrix method of contingency analysis is faster than other methods of evaluation, and is an efficient method in the selection of lines to be opened or closed in eliminating overloads. The paper will also clarify the simple concepts behind this method to make the approach more readily usable by others.

As an example, consider the simple network shown in Figure 1.

When line A is overloaded, opening line B will increase the overload in line A, while opening line C will decrease the overload in line A. The decision as a result of switching in this simple network is obvious but in a complex network it is not clear what change in the overload will occur when a remote line is switched.

The technique follows closely an algorithm to evaluate interchange capability and contingency analysis. However, the present algorithm is considerably simpler because it does not evaluate the magnitude of the change in line flows resulting from multiple contingencies. Instead, it determines only the algebraic sign of the current change resulting from a single line removal or addition. To find the line flow change that is the result of a particular line switching a simple matrix calculation is made on elements of a precalculated matrix that has been assembled and is available in the computer library.

This technique is intended to be a tool for use by system operators using their process control computer. It is assumed that the operators know lines that overload as a result of abnormal generation schedules resulting from generation overhauls or forced outages. It is also assumed that the operators have a list of lines that might be helpful in reducing overloads by removing them or adding them to the system. Details of implementation of the algorithm and the matrix operation involved in the evaluation of the test problem are in Appendix A.

The load flow program for a balanced system takes 370 seconds of computer time to converge for a thirty-nine bus system, and will require more time for a larger system. The contingency analysis program requires 130 seconds to build the Z-matrix for this system and approximately 17 seconds for each line removal or addition. Since the Z-matrix for the entire system can be calculated off-line and stored in memory, only the contingency analysis needs to be performed on-line. Therefore, the method provides a simple new tool with substantial savings in computer time.

In summary, the technique described in this paper is very fast, and can be used without taking a lot of computer time or memory. It can be applied to a real time situation where a fast and accurate method is needed to select lines to be switched in the event of a line overload. The test results prove that, in general, it is not necessary to run a load flow for each contingency evaluation; this method shows similar results in the same order as the load flow study. This technique allows for the removal and monitoring of any number of lines in the network, so that several overloaded lines may be checked at the same time.

**Discussers:** B. Wollenberg, A. S. Alfuhaid, W. R. Brownlee, N. Müller, V. H. Quintana and P. L. Dandeno

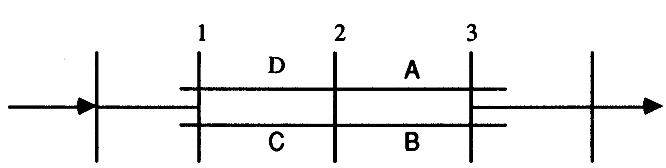


*Fig. 1. Portion of a power system.*