Available online at www.sciencedirect.com
ScienceDirect
Journal of the Franklin Institute 344 (2007) 1063–1074
Journal of The Franklin Institute
www.elsevier.com/locate/jfranklin

A method for determining generators' shares in loads, line flows and losses

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Received 18 March 2006; accepted 21 May 2007

Abstract

This paper presents a new method for calculating the individual generators' shares in line flows, line losses and loads. The method is described and illustrated on active power flows, but it can be applied in the same way to reactive power flows.

Starting from a power flow solution, the line flow matrix is formed. This matrix is used for identifying node types, tracing the power flow from generators downstream to loads, and to determine generators' participation factors to lines and loads. Neither exhaustive search nor matrix inversion is required. Hence, the method is claimed to be the least computationally demanding amongst all of the similar methods.

Keywords: Power flow tracing; Open access transmission; Energy market

1. Introduction

What fractions of the branch flows and losses are contributed by a particular generator? How much of the power output of a generator is used to supply a particular load? In a vertically integrated system, the answers to these and similar questions are of little importance.

However, in a competitive environment, such "usage allocation" questions must be answered clearly and unequivocally to ensure fairness and efficiency of the electric power market [1,2].

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0016-0032/$32.00
doi:10.1016/j.jfranklin.2007.05.004

This issue has been addressed in several works [1–10]. In Ref. [1], all power injections are translated into real and imaginary currents; contribution of each source to each sink is determined by tracing these currents. A method for determining contributions of individual active or reactive generations to branch complex loss, and contributions of individual complex generations to branch active and reactive power losses is presented in Ref. [2].

In Ref. [3], the topological generation and load distribution factors TGDF are derived based on power flow tracing methodology [4]. This method requires a matrix inversion and considers losses by introducing virtual nodes in every branch. This method was used as the basis of ex ante transmission pricing method in Ref. [5].

New concepts such as domain, commons, and links were introduced in Ref. [6] and used to determine the contributions of generators in supplying a domain, i.e. the set of buses supplied by the set of generators. The method performs a long search procedure to form the domains and commons, which has to done for active power and reactive power each time even if a slight change takes place in the power flow.

In Ref. [7], the graph theory is utilized to perform power flow tracing for systems without loop flows, and a method for dealing with loop flows was introduced in Ref. [8]. The method makes use of a number of matrices of large dimensions, which requires more time for building up and manipulation of these matrices. Moreover, it is essential for the method to determine the tracing sequence first, as most of the calculations and even the bus ordering depend upon that sequence. The method has not described how to deal with systems with more than one sink node and/or more than one source node.

The node generation distribution factors NGDF are calculated for active and reactive power flows separately in Ref. [9] based on a search algorithm, which determines the power flow directions. To overcome the time consuming feature of the search algorithm, a method based on matrix calculations is presented in Ref. [10] that analytically obtains the flow paths from sources to sinks. However, that method replaces each line by two lines; one carrying the power transfer and the other carrying losses; the direct result is to increase the dimensionality, solution time, and computation burden of the problem.

This paper presents a new method for determining the contributions of individual generators to loads and line power flows in an electrical power system. A straightforward procedure is described for downstream tracing of the power injected by generators to find out the proportions of the line flows contributed by each generator. With this information in hand, transmission losses caused by each generator and the power drawn by each load from each generator can be determined.

The proposed method has the following advantages: no exhaustive search is required; generator shares in line flows are calculated by using just one matrix; no matrix inversion required; no additional nodes are required to be added for handling losses.

The proposed flow tracing technique is applied for both active power and reactive power in the same manner. Hence, the generator share in the complex power flow in each line, and the losses incurred by it can all be accurately calculated.

The paper is organized as follows: fundamentals and main concepts of the proposed method are presented. The procedure for tracing the generator power is then introduced. Test cases on simple systems are presented along with comparisons to the most common methods. Application to the IEEE 30 bus test system is presented followed by a conclusion.