

Operational Method of Circuit Analysis

By B. L. ROBERTSON, Member A.I.E.E.
University of California, Berkeley

APPPLICATION of operational methods to circuit studies has been growing rapidly within recent years, and more and more this form of analysis is achieving greater importance as a tool for regular use in handling engineering problems. The operational calculus is found to be of invaluable service in the solution of transients and in the treatment of dynamical systems, whether of an electrical or a mechanical nature. The steady advance made in the general knowledge and use of the Heaviside operational method is shown by the increasing number of technical papers that employ it.

This article has been written because of the spreading interest definitely indicated in operational circuit analysis, and the desire on the part of many who are unfamiliar with it to understand something of the principles of its application. The intention here is not to treat with the mathematics as such or with recent developments in the operational calculus. Merely, it is the aim to present what to the writer are some of the fundamental characteristics of the operational method, to show the formulation of the operational equations for a few circuits, and to discuss briefly some of the methods by which the solutions to these equations may be obtained. Stress is given the physical reasoning behind the steps.

NATURE OF TRANSIENTS

Studies in engineering and physics give rise to problems on simple circuits, networks, and systems, these problems relating to any one of the major fields of electricity, mechanics, heat flow, sound, etc. Those of particular interest here are on transients in electrical circuits. The divisions of the field of electrical engineering in which transient analysis is of importance are many, as indicated by the applications Gardner has listed.¹

In general, the study of electrical transients is the investigation of the response of such systems to disturbances produced in them. Specifically, the analysis of transients in electrical circuits involves the determination of the variation of charge, current, voltage, power, or energy with time while the system is undergoing a readjustment. It is inherent in all

For that broad group of electrical engineers not familiar with Heaviside's operational method and its value in the analysis of electrical circuits, this article presents briefly some of the fundamental characteristics of the method and explains how it is applied, its application is illustrated by the formulation of operational equations for a few typical circuits. Although intended primarily to impart only the fundamentals of the subject to an engineer who has had ordinary mathematical training, it is hoped that the article also may serve as an introduction and guide to further study.

physical systems that even though the disturbing force may be applied instantaneously, time is required for the system to pass from one steady state condition to another. Time, therefore, is the independent variable, the quantity under investigation the dependent variable, to be expressed in the end as a function of time.

HEAVISIDE'S OBJECTIVE

Briefly stated, the objective of Heaviside in analyzing circuits was to express the solutions of the problems in terms of functions of his operators, and then to assign such significance to these relations that their interpretations would be the correct solutions to his problems. The solutions were to be obtained as directly as possible, and were to give answers without further adjustment by way of any consideration of constants or functions of integration to include boundary conditions, as must be done in solving differential equations. The great majority of problems with which Heaviside treated involved systems initially at rest, the disturbing forces thus being zero for all values of time less than zero, and taking on their normal variations after zero time. Heaviside took advantage of this fact and sought to obtain solutions that automatically applied to such boundary conditions, his developments leading to this form of operational mathematics.

The operational equation, which is the initial expression for a problem in terms of operators and the circuit constants, must contain, therefore, all information necessary to solve the problem completely. The solution to the operational equation is to be the same as that for the differential equation after initial conditions have been included, and is to yield at once the total result, which for circuit transients is the transient plus the steady state variations of the quantity studied.

Heaviside's own method of interpreting his operational functions, and in converting them into explicit functions of time, appears to be one almost entirely experimental. It would seem that he must have applied his method to problems having known solutions, and in this way determined how well his general rules worked and what he could or could not do. No doubt such steps provided him with the body of rules which he used in his analyses but on which he gave little or no discussion in his technical

Written especially for ELECTRICAL ENGINEERING, based upon an oral presentation before the A.I.E.E. San Francisco Section, San Francisco, Calif., Feb. 9, 1935.
1. For all numbered references see list at end of article.

Operational Circuit Analysis

Khalid Sayood



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