LAPLACE TRANSFORMS AND ITS APPLICATIONS

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Abstract Laplace transform is a very powerful mathematical tool applied in various areas of engineering and science. With the increasing complexity of engineering problems, Laplace transforms help in solving complex problems with a very simple approach just like the applications of transfer functions to solve ordinary differential equations. This paper will discuss the applications of Laplace transforms in the area of physics followed by the application to electric circuit analysis. A more complex application on Load frequency control in the area of power systems engineering is also discussed.

I. INTRODUCTION

Laplace transform is an integral transform method which is particularly useful in solving linear ordinary differential equations. It finds very wide applications in various areas of physics, electrical engineering, control engineering, optics, mathematics and signal processing. The Laplace transform can be interpreted as a transformation from the time domain where inputs and outputs are functions of time to the frequency domain where inputs and outputs are functions of complex angular frequency.

In order for any function of time $f(t)$ to be Laplace transformable, it must satisfy the following Dirichlet conditions [1]:

- $f(t)$ must be piecewise continuous which means that it must be single valued but can have a finite number of finite isolated discontinuities for $t > 0$.

- $f(t)$ must be exponential order which means that $f(t)$ must remain less than $Se^{-a_0 t}$ as t approaches ∞ where S is a positive constant and a_0 is a real positive number

If there is any function $f(t)$ that satisfies the Dirichlet conditions, then,

$F(s) = \int_0^\infty f(t)e^{-st}dt$ written as $L(f(t))$ is called the laplace transformation of f(t). Here, s can be either a real variable or a complex quantity.

The integral $\int f(t)e^{-st}dt$ converges if $\int |f(t)e^{-st}|dt < \infty, s = \sigma + j\omega$

A. Some Important Properties of Laplace Transforms

The Laplace transforms of different functions can be found in most of the mathematics and engineering books and hence, is not included in this paper. Some of the very important properties of Laplace transforms which will be used in its applications to be discussed later on are described as follows:[1][2]

- **Linearity**

  The Laplace transform of the linear sum of two Laplace transformable functions f(t) + g(t) is given by

  $$L(f(t) + g(t)) = F(s) + G(s)$$

- **Differentiation**

  If the function $f(t)$ is piecewise continuous so that it has a continuous derivative $f^{n-1}(t)$ of order n-1 and a sectionally continuous derivative $f^n(t)$ in every finite interval $0 \leq t \leq T$, then let, $f(t)$ and all its derivatives through $f^{n-1}(t)$ be of exponential order e^{ct} as $t \to \infty$.

  Then, the transform of $f^n(t)$ exists when $Re(s) > c$ and has the following form:

  $$L f^n(t) = s^n F(s) - s^{n-1}f(0+) - s^{n-2}f^{(1)}(0+) - \cdots - s^{n-1}f^{(n-1)}(0+)$$

- **Time delay**

  The substitution of $t - \lambda$ for the variable t in the transform $Lf(t)$ corresponds to the multiplication of the function $F(s)$ by $e^{-\lambda s}$, that is

  $$L(f(t - \lambda)) = e^{-s\lambda}F(s)$$

II. APPLICATIONS OF LAPLACE TRANSFORMS

This section describes the applications of Laplace transforms in the areas of science and engineering. At first, simple application in the area of Physics and Electric Circuit theory is presented which will be followed by a more complex application to power system which includes the description of Load Frequency Control (LFC) for transient stability studies.

A. Application in Physics

A very simple application of Laplace transform in the area of physics could be to find out the harmonic vibration of a beam which is supported at its two ends [3].

Let us consider a beam of length l and uniform cross section parallel to the yz plane so that the normal deflection w(x,t) is measured downward if the axis of the beam is towards x axis. The basic equation defining this phenomenon is as given below:

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Sugeno,2000-01-24 Concepts similar to fuzzy measure have been introduced independently in many domains in non expected utility theory cooperative game theory complexity analysis measure theory etc This book reflects all these facets It gathers survey papers written by leading researchers in the field covering a selection of most significant topics The first part is devoted to fundamental and theoretical material while the second part deals with more applied topics such as decision making and pattern recognition The book is of interest to researchers in decision making artificial intelligence applied mathematics mathematical social sciences etc   Mathematical Reviews ,2005   The Laplace Transform: Theory And Applications Schiff Joel L.,2005-01-01   The Laplace Transform Joel L. Schiff,2013-06-05 The Laplace transform is a wonderful tool for solving ordinary and partial differential equations and has enjoyed much success in this realm With its success however a certain casualness has been bred concerning its application without much regard for hypotheses and when they are valid Even proofs of theorems often lack rigor and dubious mathematical practices are not uncommon in the literature for students In the present text I have tried to bring to the subject a certain amount of mathematical correctness and make it accessible to un dergraduates Th this end this text addresses a number of issues that are rarely considered For instance when we apply the Laplace trans form method to a linear ordinary differential equation with constant coefficients any n an lY n l aoy f t why is it justified to take the Laplace transform of both sides of the equation Theorem A 6 Or in many proofs it is required to take the limit inside an integral This is always fraught with danger especially with an improper integral and not always justified I have given complete details sometimes in the Appendix whenever this procedure is required IX X Preface Furthermore it is sometimes desirable to take the Laplace trans form of an infinite series term by term Again it is shown that this cannot always be done and specific sufficient conditions are established to justify this operation

The American Mathematical Monthly ,1983   **Seismic Engineering** ,1992   *Applications and Science of Computational Intelligence IV* Kevin L. Priddy,Paul E. Keller,Peter J. Angeline,2001   **The Laplace Transform** J. L. Schiff,1999 The Laplace transform is a wonderful tool for solving ordinary and partial differential equations and has enjoyed much success in this realm In the present text the author brings to the subject a certain amount of mathematical correctness and makes it accessible to undergraduates   *Proceedings of the 1977 IEEE Conference on Decision & Control, Including the 16th Symposium on Adaptive Processes and a Special Symposium on Fuzzy Set Theory and Applications, December 7-9, 1977, Fairmont Hotel, New Orleans, Louisiana* ,1977   *Italian Journal of Pure and Applied Mathematics* ,2007

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