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*Electromechanical Dynamics*

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# Chapter 1

## INTRODUCTION

### 1.0 INTRODUCTION

The human is first of all a mechanical entity who exists in a mechanical environment. The day-by-day habits of man are dictated largely by such considerations as how rapidly he can transport or feed himself. Communication with his environment is geared to such mechanical operations as the time required for his eye to scan a page or the speed with which he can speak or typewrite. Furthermore, his standard of living is very much a function of his ability to augment human muscle for better transportation and for the diverse industrial processes needed in an advanced society.

There are two major conclusions to be drawn from these thoughts. First, the unaided human faculties operate on limited time and size scales. Thus the mechanical effects of electric and magnetic forces on ponderable bodies were observed and recorded by the Greeks as early as 500 B.C., and electricity and magnetism were developed largely as classical sciences in the nineteenth century, on the basis of unaided human observations. Coulomb enunciated his inverse square law from measurements taken with an electrical torsion balance; magnetic forces, as they influenced ponderable objects such as magnetized needles, were the basis of experiments conducted by Oersted and Ampère. These electromechanical experiments constituted the origins of the modern theories of electricity and magnetism. Faraday and Maxwell unified the subjects of electrostatics and magnetostatics into a dynamical theory that predicted phenomena largely beyond the powers of direct human observation. Thus today we recognize that electromagnetic theory encompasses not only the electromechanical effects that first suggested the existence of electric and magnetic fields but also numerous radiation effects, whether they involve radio frequency waves or x-rays. Nonetheless, when man controls these phenomena, detects their existence, and puts them to good use, he most often does so by some type of electromechanical interaction—from the simple act of turning a switch to the remote operation of a computer with a teletypewriter.

The second major conclusion to be drawn from our opening remarks is that man's need for motive power for transportation and industrial processes is satisfied largely by conversion of electric energy to mechanical energy. Energy in electric form is virtually useless, yet the largest and fastest growing segment of our economy is the electric utility industry, whose source of income is the sale of electric energy. This is eloquent testimony to the fact that electric energy can be converted easily into a variety of forms to aid man in his mechanical environment. It is remarkable that the same 60-Hz power line can supply the energy requirements of a rolling mill, a television station, a digital computer, a subway train, and many other systems and devices that provide a fuller and more comfortable life. In the vast majority of these examples electromechanical energy conversion is required because of man's basic need for mechanical assistance.

As long as engineers are concerned with making the electrical sciences serve human needs, they will be involved with electromechanical phenomena.

### 1.0.1 Scope of Application

Because they serve so many useful functions in everyday situations, *transducers* are the most familiar illustration of applied electromechanical dynamics. These devices are essential to the operation of such diverse equipment as automatic washing machines, electric typewriters, and power circuit breakers in which they translate electrical signals into such useful functions as opening a switch. The switch can be conventional or it can open a circuit carrying 30,000 A while withstanding 400,000 V 2 msec later. The telephone receiver and high-fidelity speaker are familiar transducers; less familiar relatives are the high-power sonar antenna for underwater communication or the high-fidelity shake tables capable of vibrating an entire space vehicle in accordance with a recording of rocket noise.

Electromechanical transducers play an essential role in the automatic control of industrial processes and transportation systems, where the ultimate goal is to control a mechanical variable such as the thickness of a steel sheet or the speed of a train. Of course, a transducer can also be made to translate mechanical motion into an electrical signal. The cartridge of a phonograph pickup is an example in this category, as are such devices as telephone transmitters, microphones, accelerometers, tachometers and dynamic pressure gages.

Not all transducers are constructed to provide mechanical input or output. The (electro)mechanical filter is an example of a signal-processing device that takes advantage of the extremely high  $Q$  of mechanical circuits at relatively low frequencies. Filters, delay lines, and logic devices capable of