Chapter 1

APPLIED MATHEMATICS FOR RESTRUCTURED ELECTRIC POWER SYSTEMS

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Abstract This first chapter summarizes the motivation for holding the November 2003 National Science Foundation Workshop, and provides a listing of the Workshop speakers and their presentations. It also contains an overview of the articles contained in this compilation.

Keywords: Large scale power systems, systems engineering, control systems, computational intelligence, power system restructuring, electricity market deregulation.

1. Introduction

The achievements in system engineering in advancing power system reliability and security over the last three decades, accomplished by taking full advantages of advances in computer, communication, and control technologies, are truly remarkable. For example, the economic genera-
tion commitment and dispatch with security constraints for large power systems are now routinely solved using efficient Lagrangian-relaxation methods [1] and interior-point methods [2]. State estimation with bad data and topology detection capability [3], has become a mainstay in many control centers, and has gone from being an advisory tool to being used in real-time energy price calculation [4]. Fast stability analysis has benefited from energy function analysis [5, 6, 7], which also contributed to enhanced understanding of modes of instability. Tools for analyzing voltage stability, a phenomenon not noted until the 1970’s, have been well-developed [8, 9]. It is now common for control center operators to rely on the power-voltage (P-V) sensitivity curve in determining admissible power transfer across major congested interfaces. Small-signal stability has evolved from a power system stabilizer adding damping to the local swing mode to the need to damp interarea mode oscillations based on coherency analysis [10, 11], which drives the development of the wide-area monitoring system (WAMS) installed in the western US system [12]. Flexible AC Transmission Systems (FACTS) [13], based on advances in high-voltage power electronics, allow the control of bus voltages and power flows on transmission lines, as well as provide damping enhancement [14]. More recently, artificial neural networks and genetic algorithms have been applied to several power system problems, including damping control design [15, 16, 17]. From a public policy viewpoint, the work in [18] was singularly significantly in the restructuring of the power industry originally organized as regional monopolies [19, 20].

Such accomplishments were achieved, in part, due to highly focused university research programs supported by the Energy Research and Development Agency (ERDA), Department of Energy (DOE), National Science Foundation (NSF), Electric Power Research Institute (EPRI), and many utilities and manufacturers in the US, as well as their international counterparts. In particular, this very successful research process was driven from two directions: power system problems had motivated the development of new applied mathematical tools, and conversely, advances in applied mathematics were customized to form systematic approaches to complex power system problems.

Although we can point to many successes, the August 14, 2003 Northeast US Blackout [21] is a stark reminder that the increasing complexity of interconnected power systems continues to outstrip the preparedness of automatic control and protection systems and power control centers to deal with extreme contingencies. The unprecedented magnitude of overloading on a group of transmission lines in Ohio and the subsequent redistribution and swings in power flow when these lines were tripped resulted in system conditions not foreseen in any system planning and