Power Systems

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High Performance Computing in Power and Energy Systems
High performance computing (HPC) offers significant potential in critical infrastructure applications areas like power and energy systems. Recent years have seen a dramatic increase in the performance, capabilities, and usability of HPC platforms, along with the introduction of several supporting tools, libraries, compilers, and language extensions, etc. HPC, through the use of parallelism, can deliver orders of magnitude performance gains over traditional sequential approaches, making many of the applications computationally amenable that were previously considered infeasible due to their complexity, computational intensive nature, and large execution times. HPC is already seeing widespread use in applications such as energy systems, image processing, weather prediction, fluid dynamics, power systems, bioinformatics, aerospace simulation etc. This book serves to bring together recent advances in the application of HPC in accelerating computations in complex power and energy systems. The aim of the book is to equip the engineers, designers and architects with the understanding of complex power and energy systems, and to help them leverage the potential of HPC for solving the problems arising in these areas.

Following is a brief introduction to various chapters in the book.

The chapter entitled “High Performance Computing in Electrical Energy Systems Applications” presents a brief survey of areas of HPC application in electrical energy systems. Recent results for HPC applications in simulation of electromagnetic transients, composite reliability evaluation, tuning of multiple power system stabilizers and optimization of hydrothermal systems operation are also presented.

The chapter entitled “High Performance Computing for Power System Dynamic Simulation” presents the design of the next-generation high-speed extended term (HSET) time domain simulator as a decision support tool for power systems operators. It motivates the application of HPC through detailed power system component modeling and leverages efficient numerical algorithms, especially direct sparse solvers, for enabling real-time simulations. The developed simulator is validated against commercial simulators and performance results are presented.

The chapter entitled “Distributed Parallel Power System Simulation” discusses key concepts used in designing and building efficient distributed and parallel
application software. It also discusses the challenges faced by traditional power system simulation software packages when being adapted to a modern networked enterprise computing environment.

The chapter entitled “A MAS-Based Cluster Computing Platform for Modern EMS” presents a multi-agent based cluster computing platform for implementing advanced application software of EMS. It discusses the implementation of a middleware named “WLGrid” for integrating distributed computers in Electric Power Control Center (EPCC) into a super computer. Several high performance techniques, such as task partitioning, concurrent dispatching, dynamic load-balancing and priority-based resource allocation are presented to accelerate the computation and to improve the real-time property of the whole system.

The chapter entitled “High-Performance Computing for Real-Time Grid Analysis and Operation” discusses the use of HPC in power grid applications such as state estimation, dynamic simulation, and massive contingency analysis. It compares static and dynamic load balancing techniques and also discusses look-ahead dynamic simulation for enabling faster than real-time simulation of power systems.

The chapter entitled “Dynamic Load Balancing and Scheduling for Parallel Power System Dynamic Contingency Analysis” proposes work-stealing based dynamic load-balancing technique for massive contingency analysis and compares it to traditional load balancing techniques such as master-slave load balancing techniques. It also presents computational gains achieved by using work-stealing for simulations of a large real system as compared to traditional methods.

The chapter entitled “Reconfigurable Hardware Accelerators for Power Transmission System Computation” presents design and prototype of reconfigurable hardware implemented on a Field Programmable Gate Array (FPGA) to speedup linear algebra subroutines used in system security analysis. It demonstrates the use of a specialized sparse LU decomposition hardware for gaining magnitude order speedup for power system Jacobian matrix sparse factorization.

The chapter entitled “Polynomial Preconditioning of Power System Matrices with Graphics Processing Units” discusses a GPU-based preconditioner designed to specifically handle the large sparse matrices encountered in power system simulations. It also discusses the preconditioning technique based on Chebyshev polynomial, and compares the GPU implementation with CPU implementation to show the computational gains by using GPU.

The chapter entitled “Reference Network Models: A Computational Tool for Planning and Designing Large-Scale Smart Electricity Distribution Grids” discusses reference network models (RNMs) which are large-scale distribution planning tools that can be used by policy makers and regulators to estimate distribution costs. This enables the distribution companies to meet the regulations and move towards the era of a low-carbon, sustainable power and energy sector.

The chapter entitled “Electrical Load Modeling and Simulation” discusses the challenges of load modeling and its impact on the performance of computational models of the power system. It also discusses the natural behavior of electrical loads and their interactions with various load control and demand response strategies.
The chapter entitled “On-Line Transient Stability Screening of a Practical 14,500-bus Power System: Methodology and Evaluations” presents a methodology for on-line screening and ranking of a large number of contingencies. It also discusses the computational gains achieved from the proposed methodology and its suitability for real-world deployment.

The chapter entitled “Application of HPC for Power System Operation and Electricity Market Tools for Power Networks of the Future” presents an approach for using HPC to solve core optimization problems in grid operations and planning. It also highlights the benefits obtained from using HPC in increasing the operational standards and the level of renewable energy integrated into power system.

Researchers, educators, practitioners and students interested in the study of high-performance computing in power and energy systems should find this collection very useful. This book should also serve as an excellent state-of-the-art reference material for graduate and postgraduate students with an interest in future efficient and reliable power grid with large renewable energy penetration.
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