The Application of High-Performance Parallel Computing to Production Cost Simulation

Proposal for the 1994 NYS/ERDA University-Industry Energy Research Program

Northeast Parallel Architectures Center,
Syracuse University, Syracuse NY

Power Systems Engineering Department,
General Electric Industrial and Power Systems, Schenectady NY

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PART 1. TECHNICAL PROPOSAL

Abstract

This project addresses the application of parallel computing to improve the performance of a leading program for production costing used in power system planning studies.

The Multi-Area Production Simulation (MAPS) program developed by the General Electric Power Systems Engineering Department is used to study the management of power system generation and transmission resources to minimize generation production costs while considering transmission security. It is used extensively by the New York Power Pool and New York State utilities for production costing and planning studies.

Most of the computational time in running the MAPS program is in solving a large optimization problem (the hourly secure dispatch problem) using a linear programming routine. The aim of this project is to develop methods to greatly improve the performance of the linear programming section of MAPS.

The clear trend in cost-effective high-performance computing is the use of scalable parallel computers. These machines can only be effectively utilized if the existing methods or algorithms used in programs for standard sequential computers are re-analyzed and parallel algorithms are developed. The Northeast Parallel Architectures Center (NPAC) at Syracuse University is a world leader in the development and application of parallel computing technologies and parallel algorithms.

Our goal is to improve the performance of the core linear programming routine used in the MAPS program by implementing a parallel version of this routine that can be used on commercial high-performance parallel computers. We also aim to investigate the possibility of using alternative linear programming algorithms to increase the speed of the program even further. This improvement in performance will greatly enhance the application of the program to power system production costing and optimization studies, which is a key area of power system planning.

We propose a one year project to develop an improved, parallel algorithm for the linear programming kernel of the GE MAPS program, and to implement this using an industry standard parallel language in a program that can be run on commercial high-performance parallel computers.

Background/Approach

The trend toward increased buying and selling of power between utilities and independent power producers requires larger scale production costing simulations for power system planning. In New York State, this involves simulations incorporating the entire New York Power Pool, as well as neighboring utilities, in particular Ontario Hydro and the New England and PJM power pools. This means transmission costs and constraints must be included into any realistic production costing and planning studies.

These complex simulations are handled by the Multi-Area Production Simulation (MAPS) program developed by General Electric Industrial and Power Systems. The MAPS program

provides an accurate through-time simulation of production costs and network flows, taking into account generation, transmission, loads and transactions. The generation component uses hourly calculations for commitments and dispatches, always monitoring the anticipated post-contingency conditions (a secure dispatch), and meeting company or pool demands.

MAPS is the only production simulation program that incorporates realistic modeling of transmission as well as generation. Due to the detailed modeling and the large scale of these simulations, which involve many utilities and estimate costs per hour for an entire year or more, running the MAPS program on high-end single-processor workstations can be very time-consuming, taking up to 5 hours per simulation. Reducing this time would greatly aid in planning studies, by allowing many more alternative scenarios to be considered, to try to find the most cost-effective utilization of transmission and generation facilities over a large area.

Parallel processing is at the leading edge of high-performance computer technology. It offers a much more cost-effective solution than traditional mainframe and vector supercomputer technologies. Parallel computers are now being offered by leading computer vendors such as IBM, Digital Equipment Corporation (DEC), and Hewlett-Packard, and industry standard parallel languages have recently been developed. These developments are bringing parallel computing toward the mainstream of computing, and making it much more attractive for industrial applications.

There is enormous potential for the application of parallel computing in many areas in the utility industry. A study done for ESEERCO by TASC (ESEERCO Project EP-90-10) showed that savings of millions of dollars per year are possible for New York State utilities by the improved simulations that would be allowed by the use of high-performance computing. However power utilities (and many other industries) are wary of investing in this new technology, since it involves not only new hardware, but in many cases new or modified software as well. There is a need to create exemplar applications for parallel computers to show that this new technology can truly benefit the utility industry. This project aims to provide such an application in an important area of utility management.

MAPS is the only commercially available program that includes realistic transmission modeling and security constraints into production costing simulation. However the price of such detailed and accurate modeling is that simulation times can be quite long. The results of this project would be used to improve the performance of the MAPS program. This would provide utility planners with faster turn-around time for their simulations, and allow them to explore a wider range of possible scenarios for network planning studies. This would result in better optimization strategies for the development of power networks, and more cost-effective utilization of these networks.

The MAPS program is currently used by the following New York State organizations for production costing and planning studies:

- New York Power Pool
- Long Island Lighting Corporation
- Niagara Mohawk Power Corporation
- Consolidated Edison Corporation

- New York Power Authority
- New York State Energy Office

MAPS has been used for cost/benefit studies of pooling, new power contracts and wheeling arrangements, installing new transmission capability between neighboring utilities, development and siting of new generation facilities, retiring generators and using more energy imports, introduction of VAR compensation, line reconductoring, redispatching generation to meet environmental goals, and many other applications, including optizing the use of phase angle regulators to reduce unwanted loop flows.

All of these studies allow the development of more cost-effective solutions and provide substantial savings, as well as reduction of energy use and environmental impact. Greater savings could be achieved if the performance of the MAPS program could be improved.

Statement of Work

Introduction

The goal of this project is to improve the speed of solution of the most time-consuming portion of the MAPS program for production cost simulation, which is the determination of optimal power generation with transmission limits, or the "secure dispatch" problem for hourly intervals over time periods on the order of a year. This is to be done by developing and implementing improved parallel algorithms for the linear programming routine used to solve the secure dispatch problem.

The programs will be developed using the IBM SP-1 parallel computer at NPAC, which is an integrated collection of standard IBM RS/6000 workstations connected by a switched high-speed communications network. The program development will be done using industry standard parallel languages, so that the resulting program will be portable to any parallel computer, including networks of workstations linked by standard Ethernet connections.

GE will work with NPAC to provide a formulation of the problem and sample power system data. NPAC will then work to develop methods for improving the performance of the linear programming module, by studying alternate sequential algorithms and developing parallel algorithms. This will involve input from GE, since improving the performance of the parallel algorithm may involve using different approximations and techniques for modeling the problem than those used to obtain the best performance for a sequential program. New algorithms for this problem will be developed, implemented, benchmarked, and compared in terms of simulation time and accuracy of results.

Project Management

Team members from the Northeast Parallel Architectures Center (NPAC) will meet with members from General Electric (GE) when needed, to discuss the details of the program, the algorithms used, any necessary implementation details, and to discuss progress and plans. Much of the interaction between NPAC, GE and external advisors can be done remotely by telephone and electronic mail.

Team members from NPAC and GE will make themselves available to the Energy Authority for an initial meeting and quarterly project review meetings as required.

Technology Transfer

NPAC will apply parallel computing techniques and improved algorithms to develop and implement a fast parallel linear programming algorithm for solving the hourly secure dispatch problem that is the computational core of the GE MAPS program. GE would then be able to integrate this improved parallel linear programming algorithm into the MAPS program, to greatly reduce the run-time of the program, thereby increasing the utility and scope of application of the program.

The New York State institutions that would be interested in the results of the final report are the New York Power Pool plus NYPP member utilities, and the New York State Energy Office.

The results of this work will be presented at conferences and submitted to journals related to both power systems computing and parallel computing.

Research, Development and/or Demonstration Tasks

The following tasks will be required to research the problem and develop and document the parallel algorithms and programs:

1. A thorough study of the MINOS linear programming algorithm that is the basis of the optimization routine used in MAPS program.

2. A study of how the secure dispatch optimization problem is formulated within the MAPS program, concentrating on features such as what approximations and assumptions are made in modeling the problem, and a study of how the linear programming algorithm is used within the MAPS program.

3. A study of alternate linear programming techniques and software and an investigation of their applicability to this problem.

4. The implementation of alternate linear programming algorithms which seem likely to offer better performance than MINOS, and a comparison of the results with MINOS.

5. Research to develop parallel algorithms for the linear programming routine.

6. Development of programs to implement the parallel linear programming algorithms.

7. Benchmarking of the performance of the various parallel programs on commercial parallel computers, and a comparison of the performance with the current sequential linear programming algorithm, using power system data provided by GE.

8. Documentation of the program and preparation of technical papers for presentation in appropriate journals and conferences.

Reporting

Quarterly progress reports will be presented to ERDA. A final report will be presented at the end of the project. These reports will describe the development of parallel linear

programming algorithms, investigations into the use of alternate linear programming algorithms, the implementation of these algorithms, and the benchmarking and comparison of these algorithms on various parallel computers.

Schedule

The schedule of work shown here is for the tasks enumerated above.

Organization and Effort

The project team members will be:

- **Northeast Parallel Architectures Center, Syracuse University**
  Dr Paul Coddington (Project Manager)
  Professor Geoffrey Fox
  Alexander Mintskovsky
- **General Electric Industrial and Power Systems**
  Dr Nelson Simons (GE team manager)
  Dr Len Garver
  Rana Mukerji

Resumes for all team members are enclosed at the end of part 1 of the proposal.

The following table shows the number of hours each person will devote to the tasks enumerated above.

	TASK								
	1	2	3	4	5	6	7	8	TOTAL
Coddington	20	40	30	10	100	80	20	116	416
Mintskovsky	100	150	300	260	400	400	120	350	2080
Fox	0	0	20	0	60	10	0	14	104
Garver	0	16	0	0	8	0	8	8	40
Mukerji	0	32	0	0	8	0	16	16	72
TOTAL	120	238	350	270	576	490	164	504	2712

Professors Bill Bixby and John Dennis of Rice University are leading experts on optimization and linear programming algorithms, and will be advising us in these areas. NPAC and Rice University are members of the national Center for Research on Parallel Computation.

Team Expertise

NPAC is a world-class organization for research in parallel computing. It is a member of the national Center for Research on Parallel Computation (CRPC). Geoffrey Fox, the director of NPAC, is a world-renowned expert in parallel computing who was heavily involved in the early development of parallel computers and algorithms while at the California Institute of Technology.

NPAC has a large on-going program (ACTION/InfoMall) for industrial applications and technology transfer. This technology transfer program is focussed on New York State companies, and NPAC is involved in joint projects with many large corporations, including IBM, NYNEX, Martin Marietta, and Niagara Mohawk Power Corporation, as well as a number of smaller software development companies.

NPAC has outstanding networking and computing facilities, including state-of-the-art parallel machines such as the IBM SP-1, DEC Alpha Gigaswitch cluster, Thinking Machines CM-5, Intel iPSC, nCUBE/2, and DECmpp. Through involvement with CRPC, we have access to other parallel supercomputers, as well as state-of-the-art expertise in many areas of high-performance computing and communications. CRPC includes some of the finest research groups in the world in the field of optimization and linear programming, so we have access to the best methods in this area.

NPAC is currently involved in a project with Niagara Mohawk Power Corporation, to investigate the use of high-performance parallel computing for utility applications. This project, which is currently being led by Dr Paul Coddington, is concentrating mainly on improving the performance of security model programs for both planning studies and on-line

simulations for the control room Energy Management System, and in developing parallel sparse matrix algorithms, which are used in many power system simulations. Niagara Mohawk are major users of the MAPS program, and are very interested in the results of this project.

Alexander Mintskovsky, who will be performing most of the research and development work for this project, has previously worked with the Energy Research Institute at Syracuse University on software related to utility applications, including forecasting gas distribution requirements, and detecting wear in nuclear power station components.

The Power Systems Engineering Department (PSED) is a component of General Electric Industrial and Power Systems. Located in Schenectady, New York, the Department is under the leadership of Thomas F. Garrity. The GE PSED group working on this project have been heavily involved in the development of the MAPS program for many years.

PSED has a long history of involvement in utility and industrial power and energy systems engineering and plays a key role in the design and evaluation of these systems. In fulfilling this role, PSED provides guidance to GE product departments, and electric utility and industrial customers concerning the development, application and testing of power system equipment. In addition, PSED is actively participating in research and development programs aimed at developing and commercializing advanced energy and systems technologies. Through these systems engineering efforts, PSED supports GE components, electric utilities and agencies such as the Electric Power Research Institute and the U.S. Department of Energy.

The strength of PSED lies in the capabilities of personnel whose power systems engineering experience represents more than 1,500 man-years. Programmers, engineering assistants, and secretaries support the engineering personnel in order to provide PSED with a balanced capability for analyzing both present and future power systems.

The Power Systems Engineering Department is the seat of GE's scientific and engineering competence in the field of electric bulk power systems. Its precursor was the Central Station Engineering Division, formed in the early days of the electric utility industry, when the industry was plagued with very practical and perplexing problems of synchronous stability and surge phenomena. Early and modern pioneers in this division developed the basic theory of operation of synchronous systems, of lighting and switching surge phenomena, of economic operation of generation, and of the reliability of generation systems. Their names – Park, Doherty, Clarke, Crary, Kron, Concordia, Kirchmayer – are familiar to those who are acquainted with electric utility system technology. Today's PSED, schooled in the traditions of these people, has become an organization of unusual breadth as well as depth in the field of electric utility energy systems. Its intimate knowledge of electric utility practices and requirements makes it the ideal vehicle for studies of electric utility power system performance. It has increasingly applied its talents to the needs of the electric utility industry and agencies of state and federal governments.

The following is a list of recent publications by team members that are relevant to this project:

1. L.L. Garver, G.A. Jordan, D.A. Keegan and N.W. Simons, The Integrated Effects of Generation and Transmission on Annual Production Costs, EPRI Conference on Applications of Power Production Simulation, Washington, DC, June 1990.

2. N.W. Simons, L.L. Garver, R. Mukerji, Transmission Constrained Production Costing: A Key to Pricing Transmission Access, Public Utilities Fortnightly, vol. 131, no. 3, 1993.

3. G.C. Fox, Parallel Computing in Industry – An Initial Survey, Proceedings of the Fifth Australian Supercomputing Conference, Melbourne, 1992.

4. K. Mills and G.C. Fox, High Performance Computing and Communications Applications Development and Technology Transfer to Industry, Proceedings of The New Frontiers: A Workshop on Future Directions of Massively Parallel Processing, IEEE Computer Society Press, Los Alamitos, CA, June 1993.

5. InfoMall: A Scalable Organization for the Development of HPCC Software and Systems, NPAC technical report SCCS-531.

6. D.P. Koester, S. Ranka, and G.C. Fox, Power Systems Transient Stability – A Grand Computing Challenge, NPAC technical report SCCS-549.

7. D.P. Koester, S. Ranka, and G.C. Fox, Parallel Block-Diagonal-Bordered Sparse Linear Solvers for Electrical Power System Applications, Proceedings of the Scalable Parallel Libraries Conference, October 1993, IEEE Press.

8. K. Anupindi, P. Coddington, G.C. Fox and A. Skjellum, Parallel Differential Algebraic Equation Solvers for Power System Transient Stability Analysis, Proceedings of the Scalable Parallel Libraries Conference, October 1993, IEEE Press.

9. G.C. Fox, P. Coddington, A. Choudhary, S. Hariri, M. Nilan and S. Ranka, High Performance Computing and Parallel Processing in the Utility Industry: Final report for Phase 1, NPAC report SCCSI-542 for Niagara Mohawk Power Corporation.

Cost-Sharing

Energy Authority	54.3%
University team member	
– actual dollars	9.9%
– in-kind	27.2%
Industrial team member	
– actual dollars	8.6%
– in-kind	–
Other sources:	–
	100%

Royalties

GE is willing to negotiate a royalty for ERDA if a commercial parallel MAPS program is developed that uses the results of this project. GE has already invested approximately

$10M in developing the MAPS program, so the amount of royalty for the $100K ERDA investment in this project would necessarily be quite small.

Letters of Commitment

Letters of commitment from Syracuse University and General Electric are enclosed.