Power Systems Reliability Evaluation on Parallel and Distributed Processing Environments

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Power Systems Reliability

- Main Objective: Satisfy demand as economically as possible with continuity, quality and security
- Random failure of components can lead to power supply interruption and quality degradation
- Financial investments are necessary to increase system reliability and to reduce the probability, frequency and duration of failure events
- Power supply reliability evaluation is fundamental to establish transactions in the new competitive electric energy market

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Composite Reliability using Monte Carlo Simulation

- Analysis of a very large number of system operating states for different load levels and scenarios
- System state analysis requires simulation of the system behavior under contingency satisfying operation and security restrictions
  - ➔ Demands high computational effort
- The many system states analyses may be performed independently from each other
  - ➔ PARALLEL/DISTRIBUTED PROCESSING

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Conceptual Algorithm

←Select an operating scenario ***x*** corresponding to a load level, components availability, operating conditions, etc.

↑ Calculate an evaluation function ***F(x)*** which quantifies the effect of violations in the operating limits in this specific scenario.

→Update the expected value of the reliability indexes based on the result obtained in step 2.

↓ If the accuracy of the estimates is acceptable, terminate the process. Otherwise, return to step 1.

Basic Functions

- *States Selection*: Obtain a sample of random vector $\boldsymbol{x} = (x_1, x_2, \ldots , x_n)$ by sampling the components operating states probability distribution
- *States Adequacy Analysis*: Contingency Analysis (large sets of nonlinear algebraic equations) and Optimal Power Flow (large scale nonlinear programming problems) ➔ Concentrates the computational effort
- *Reliability Indexes Calculation*

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Parallelization Strategy

- Parallelization of system states adequacy analysis (coarse grain parallelism)
- Master - Slaves Paradigm
  - Master: data flow and parallel convergence control, reliability indexes calculation
  - Slaves: system states analysis
- Communication Requirements
  - Initial distribution/Final grouping of data
  - Control of global parallel convergence

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States Distribution Philosophy

- Parallel generation of random numbers sequences: avoid correlation between sequences generated in different processors
- System states generated directly at the processors in which they are analyzed
- All processors receive the same seed and execute the same random numbers sampling
- Each processor starts to analyze the state with a number equal to its rank and analyzes the next states using as step the number of processors

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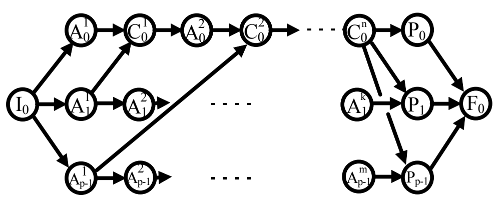
Task Allocation Graph



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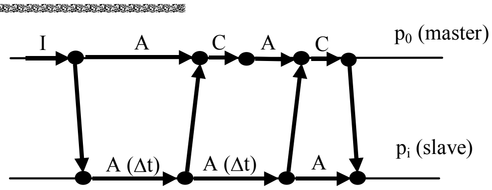
Precedence Graph



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Parallel Implementation

- IBM RS/6000 SP: Scalable parallel computer with distributed memory
  - 10 POWER2 processors
  - high performance switch: 40 MB/s full-duplex
- Cluster of PCs based on Windows NT
  - 8 Intel Pentium III 500MHz
  - Fast Ethernet: 100 Mbits/s
- Message passing system: MPI

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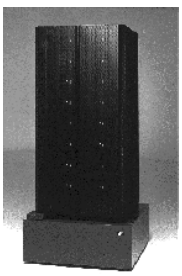
IBM RS/6000 SP



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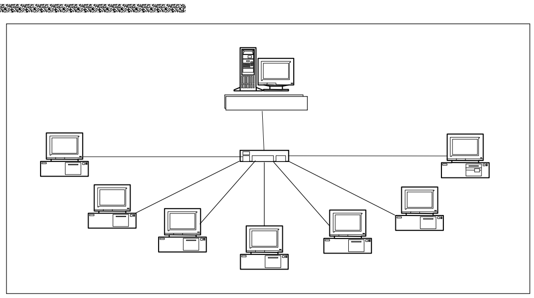
Cluster of PCs



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RS/6000 SP Results

System	Sequential	Parallel	Efficiency (%)
BR-NNE	6.18 min	39.91 s	92.9
BR-S	8.03 min	51.80 s	93.0
BR-SE	2.78 h	17.36 min	96.1

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Cluster of PCs

System	Sequential	Parallel	Efficiency (%)
BR-NNE	1.85 min	17.42 s	79.7
BR-S	2.77 min	23.75 s	87.5
BR-SE	1.08 h	8.48 min	95.5

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Conclusions

- Speedup almost linear and efficiency higher than 90% for larger system
- Good scalability
- High performance is due to the combination of three aspects:
  - Degree of parallelism inherent to the problem
  - Coarse grain parallelization strategy adopted
  - Asynchronous implementation developed

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