TDPSS: A Scalable Time Domain Power System Simulator For Dynamic Security Assessment

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Presentation Plan

- Motivation
- TDPSS Flow-diagram
- Architecture and Application View
- Modeling and Design View
- TDPSS Efficiency
- Validation Results
- Performance Results
- Summary

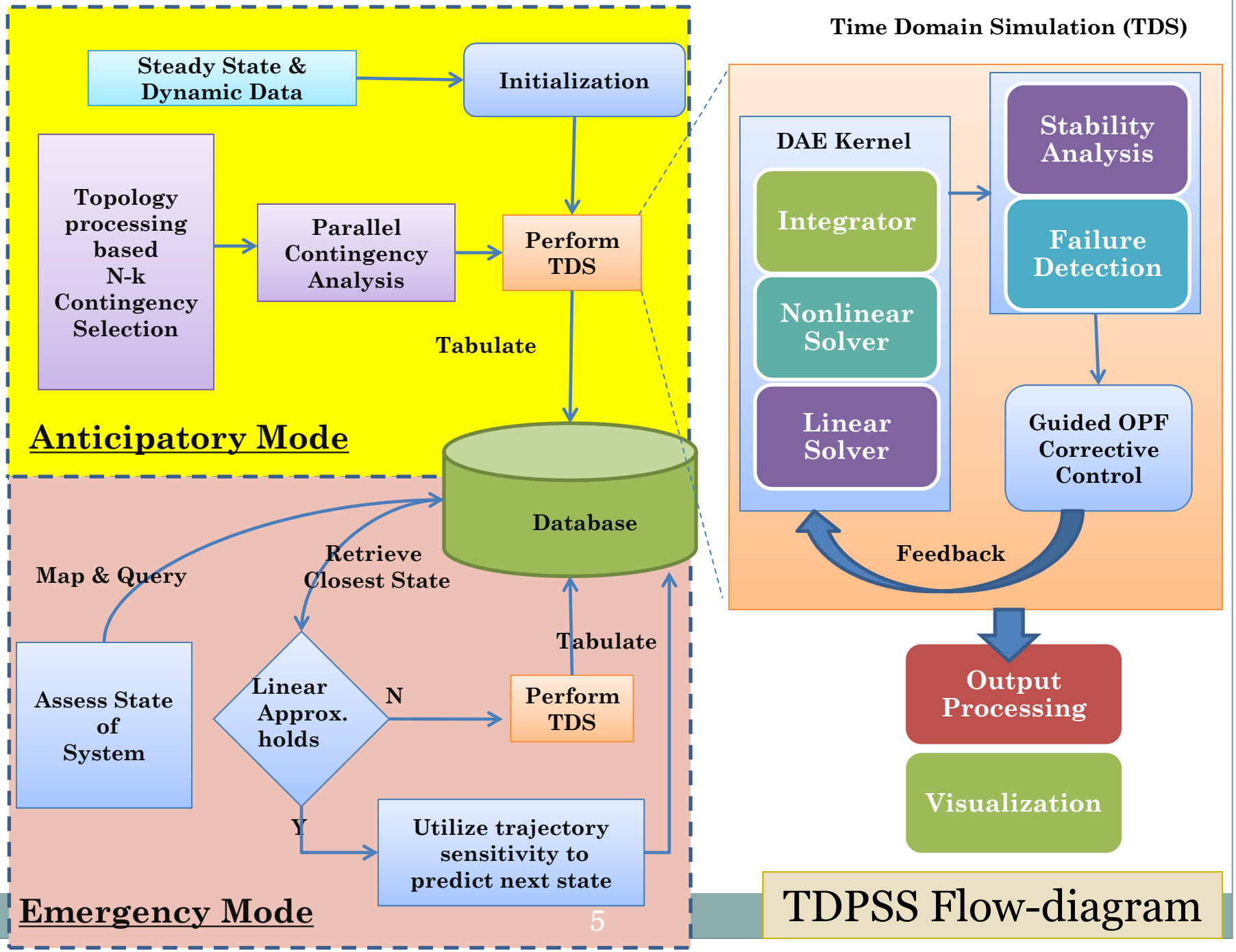
Motivation

- Modern power systems: large and complex
- Requirement of N-*k* contingency analysis
- Existing simulators: slow, force designers to test with old systems.
- Cannot explore trade-off b/w speed and accuracy
- Inefficient for security assessment

- We need efficient simulators for security assessment!

TDPSS Features

- Works in two modes: anticipatory & emergency
- Provides models for different power sys. components
- Provides different numerical solvers
- Designed with object oriented programming
- High simulation speed
- Validated against commercial software packages
- Research grade: allows easy exploration!



TDPSS Flow-diagram

Architecture and Application View

- Works in two modes: anticipatory & emergency
- Anticipatory:
  - Normal mode of operation
  - Analyze most contingencies, store results.
  - Cover large probability space
- Emergency:
  - Switch to it at time of disturbance
  - Reuse stored results for fast response

Architecture and Application View

- Tested with many different systems, ranging from 9 bus system to 13029 bus system.
- Useful for a variety of studies
  - Finding critical clearing time of contingencies
  - Analyzing voltage and rotor angle stability
  - Decision support tool
  - Dynamic security assessment tool
- Useful for modern control centers.

Design and Modeling View

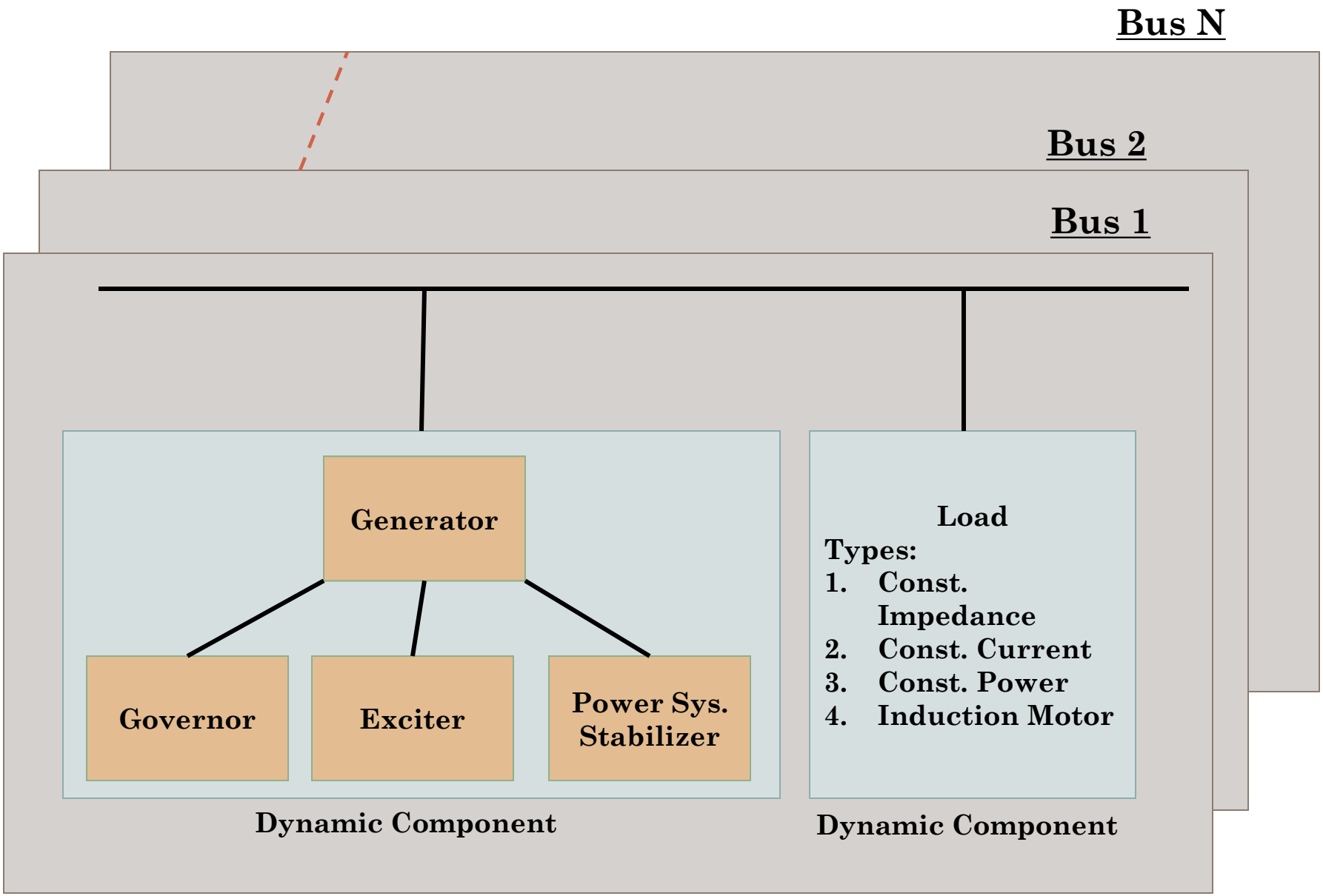
- Mathematical Modeling
  - Extensive library of generators, governors and exciters
  - Numerical Solvers:
    - Integration solvers: IDAS (BDF), TR, HH4, Euler,
    - Linear solvers: KLU, UMFPACK, PARDISO, SuperLU, WSMP, MUMPS, HSL,
    - Non-linear solver: VDHN

- Enables exploring trade-off between speed and accuracy

Design and Modeling View

- Simulation Modeling
  - Cross platform simulator, designed in C++
  - Designed using object-oriented programming. Features:
    - Inheritance
    - Composition
    - Modularity
    - Encapsulation and message passing
    - Dynamic memory allocation
    - Event-driven simulation
- Enables code-reuse, easy extension and natural translation of real-world relationships.

Conceptual Illustration of Power System



Corresponding Object-Oriented Program in TDPSS

```
class BusModel
{
        GeneratorNode genNode;
        ExciterNode excNode;
        GovernorNode govNode;
        LoadNode loadNode;
        BreakerNode breakerNode;
        BranchNode branchNode;
};
```

TDPSS Efficiency

- Computational Efficiency
  - Uses best available linear solvers and integration solvers
  - Configurable accuracy
- Simulation Efficiency
  - C++ is compiled language and hence, faster than MATLAB (in general).
  - Compiler optimization and easy debugging
  - Plotting and visualization separate from execution to avoid overhead
  - Can be used with plotting tools (e.g. gnuplot) for visualization.

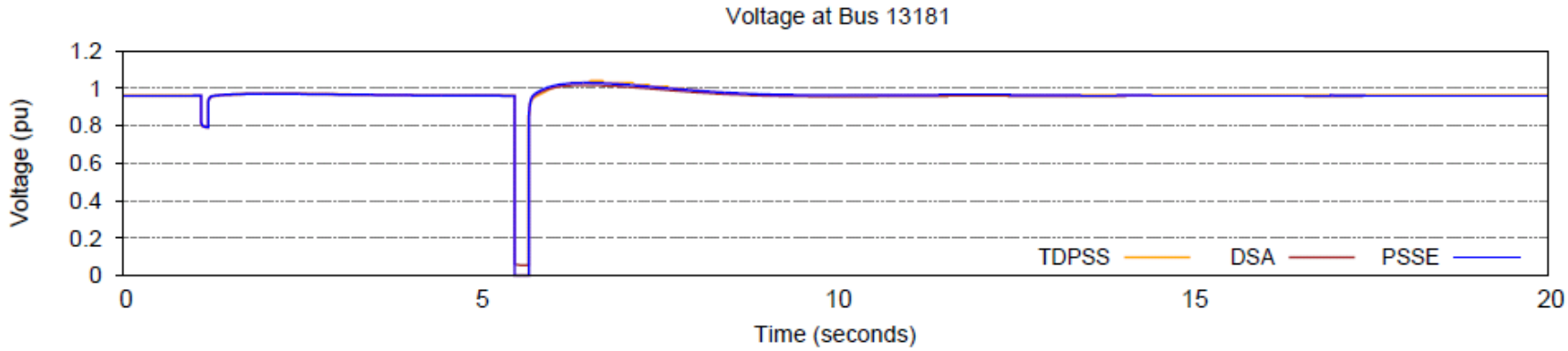
TDPSS Validation Results

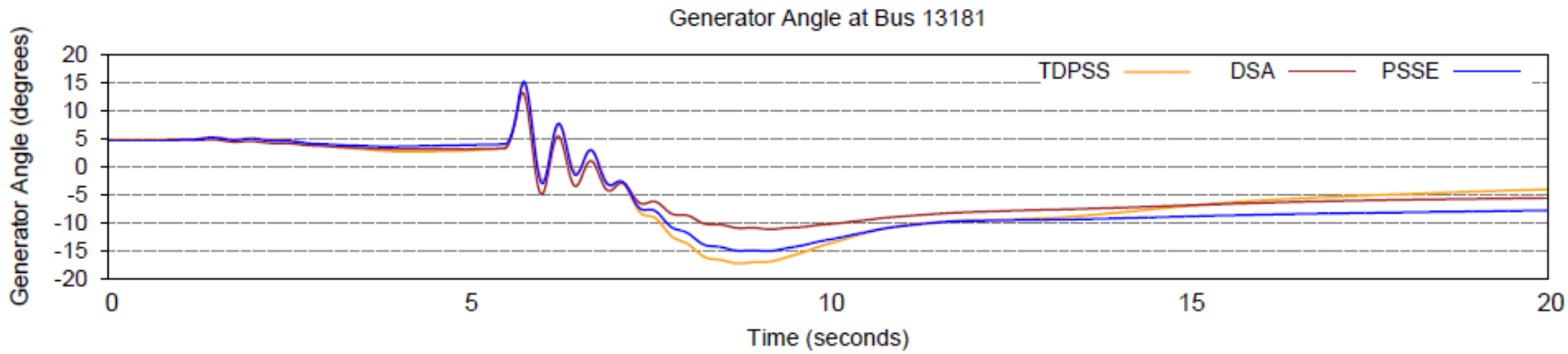
- Power system: 13029 buses, 431 generators, 12488 branches and 5950 loads.

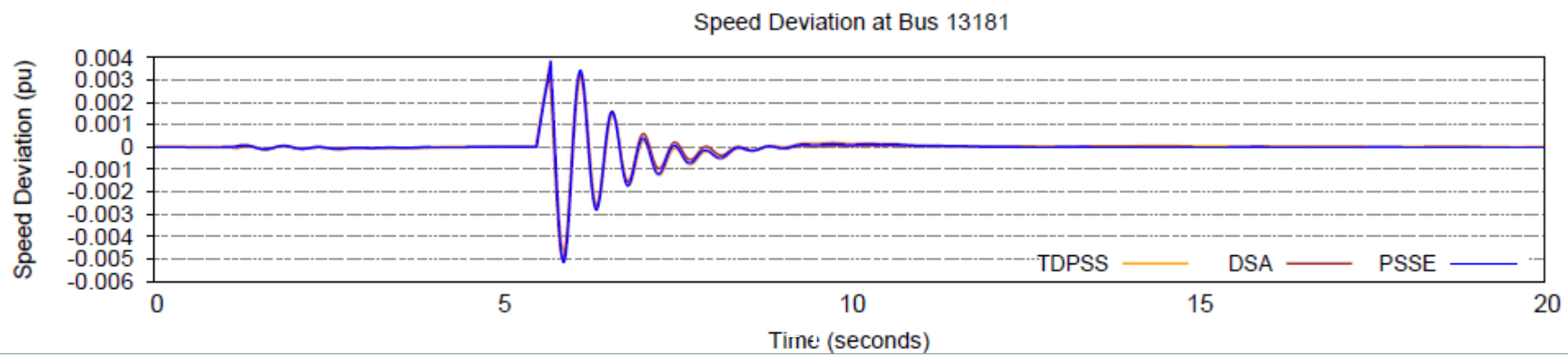
- Contingency C1: Bus fault at 13179 at 1.1 sec which is cleared at 1.2 sec; branch fault at 13181-13182, at 5.5 which is cleared at 5.7. Simulation run for 20 sec.

- Commercial packages: DSA and PSSE.

TDPSS: Validation Against DSA and PSSE







TDPSS Performance Results

- Contingency C2: Bus fault at 26 (which is a generator bus) at 1.1 sec, which is cleared at 1.2 sec. Simulation run for 20 sec.

- We tested different linear solvers, viz.
  - KLU
  - UMFPACK
  - PARDISO

TDPSS: Simulation Time For Different Linear Solvers

	Simulation Time (seconds)			**Speedup**	
	KLU	*UMFPACK*	*PARDISO*	*UMFPACK/KLU*	*PARDISO/KLU*
1	19.5	46.5	34	2.4	1.7
2	11.3	23.7	21	2.1	1.9

KLU is nearly 2 times faster than other solvers!

TDPSS Performance Results

- We compare speed of TDPSS against PSSE software.

TDPSS: Speed Comparison with PSSE

	Simulation Time (seconds)		**Speedup**
	TDPSS	*PSSE*	*PSSE/TDPSS*
1	19.5	39	2
2	11.3	38.6	3.4

TDPSS is more than 2 times faster than PSSE!

Extensions

- Automatic Generation Control
  - To hold system frequency at or very close to specified nominal frequency.
  - To maintain the correct value of interchange power between control areas.
  - To maintain each unit's generation at the most economic value.
- Parallelization (Multicore and Distributed Platforms)
  - By contingency
  - Linear Solvers
- Power Saving
  - Cache
  - DRAM

Summary

- Works in two modes: anticipatory & emergency
- Provides models for different power sys. components
- Provides different numerical solvers
- Designed with object oriented programming
- Validated against commercial software packages
- High simulation speed: faster than commercial package.
- Allows easy exploration between speed and accuracy!

Thank You!

QUESTIONS AND COMMENTS ARE WELCOME!

Extra Slides