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Implementation of Temporal Parallelization for Rapid Quasi-Static Time-Series (QSTS) Simulations

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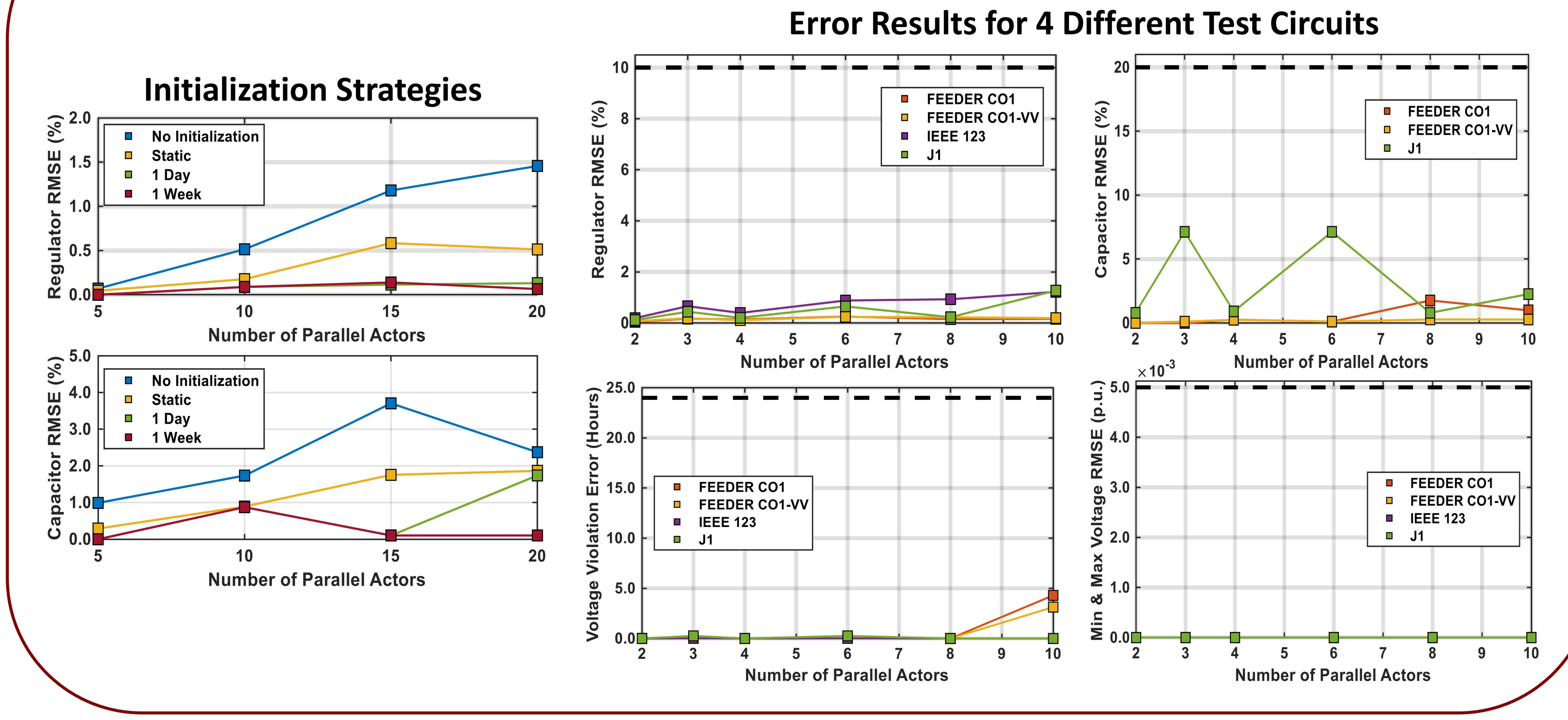
Abstract

Quasi-static time-series (QSTS) analysis of distribution systems can provide critical information about the potential impacts of high penetrations of distributed and renewable resources, like solar photovoltaic systems. However, running high-resolution yearlong QSTS simulations of large distribution feeders can be prohibitively burdensome due to long computation times. Temporal parallelization of QSTS simulations is one possible solution to overcome this obstacle. QSTS simulations can be divided into multiple sections, e.g. into four equal parts of the year, and solved simultaneously with parallel computing. The challenge is that each time the simulation is divided, error is introduced. This paper presents various initialization methods for reducing the error associated with temporal parallelization of QSTS simulations and characterizes performance across multiple distribution circuits and several different computers with varying architectures.

Error Results

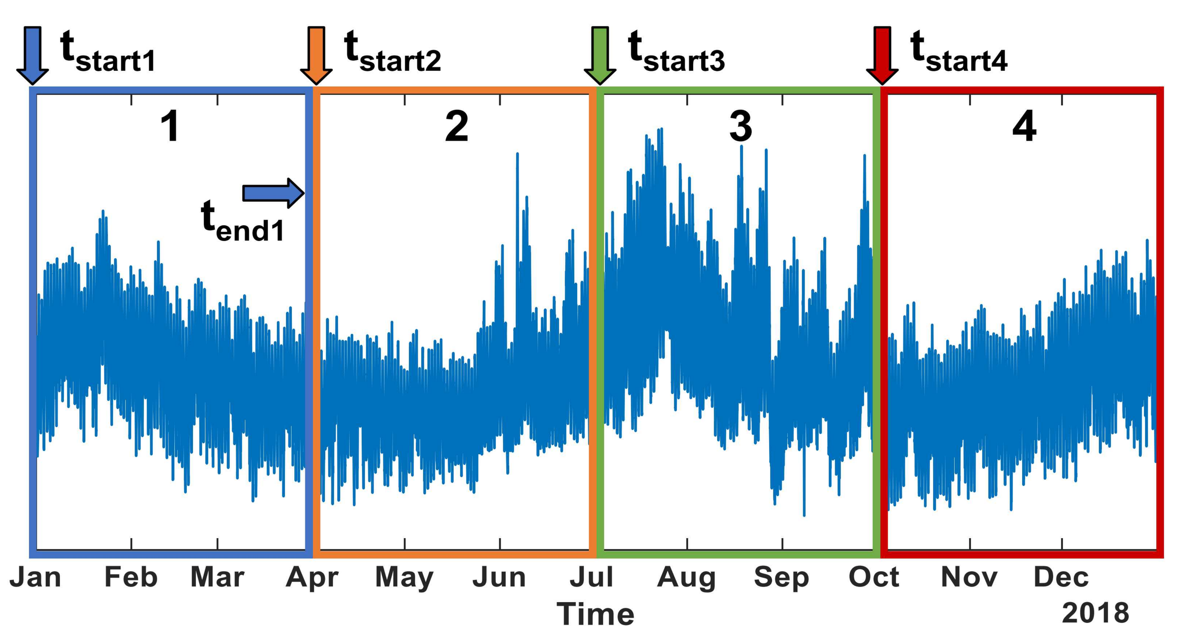


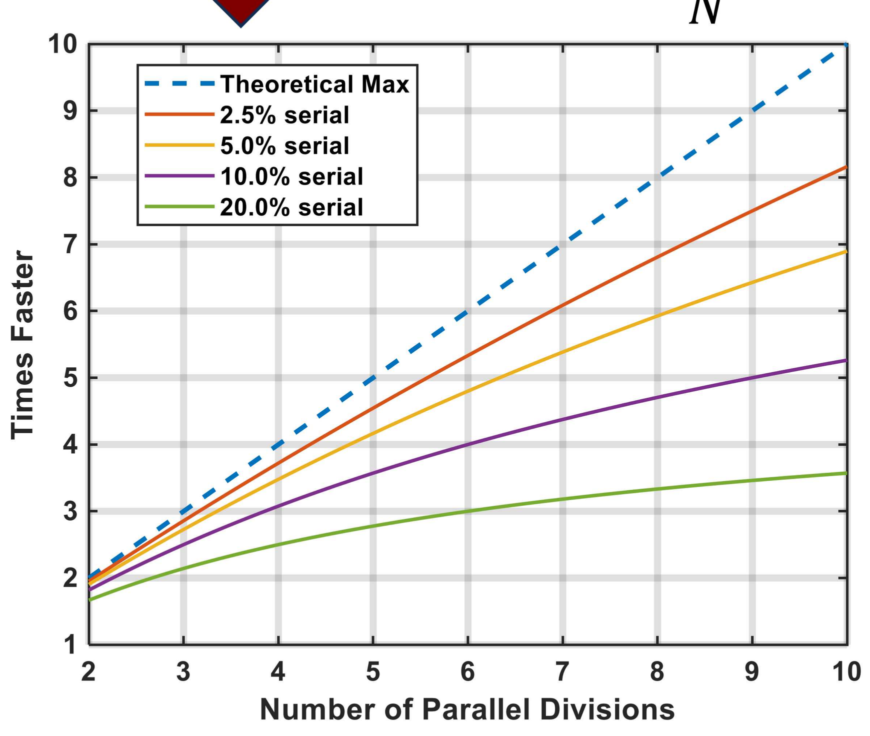
Temporal Parallelization

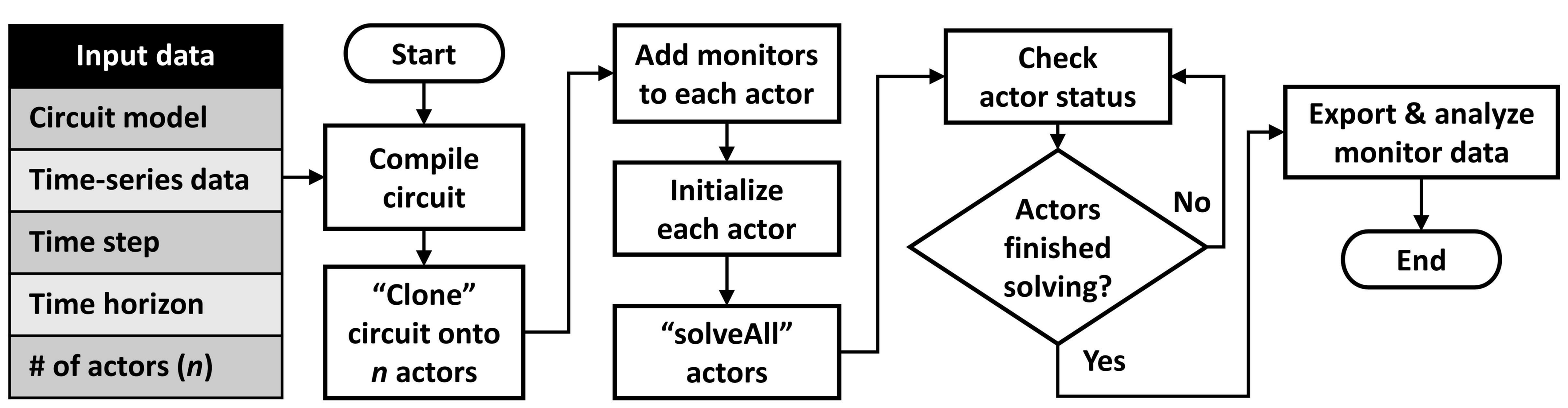
- QSTS simulations can be divided into multiple sections, e.g. into four equal parts of the year, and solved simultaneously in OpenDSS using the built-in parallel computing functions (see flowchart)
- Since each power-flow solution can have more than one valid solution, the calculated states at each temporal division may differ from the actual base-case states which introduces error
- The upper bounds of expected speed improvements can be captured by Amdahl's law, where S is the serial component of the application and N is the number of parallel divisions

Amdahl's Law

$$Times\ Faster = \frac{1}{S + \frac{(1-S)}{N}}$$

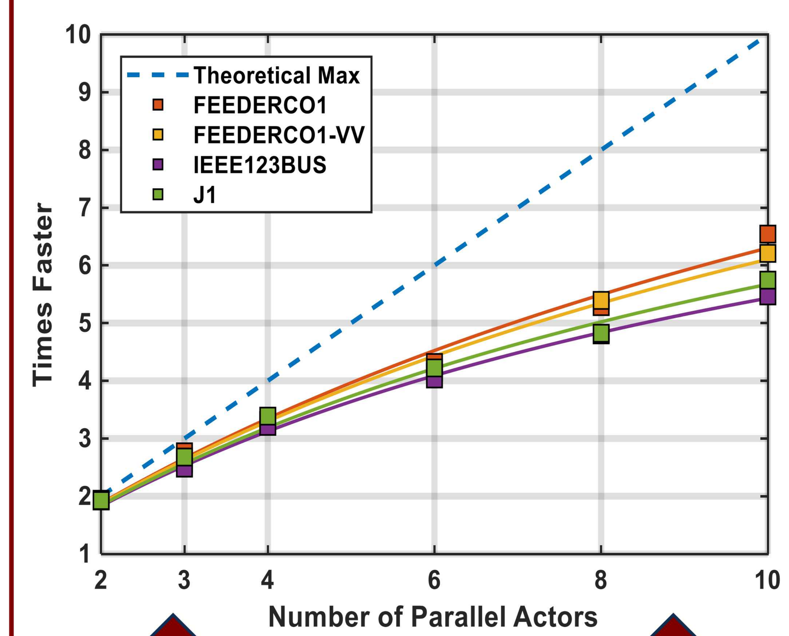


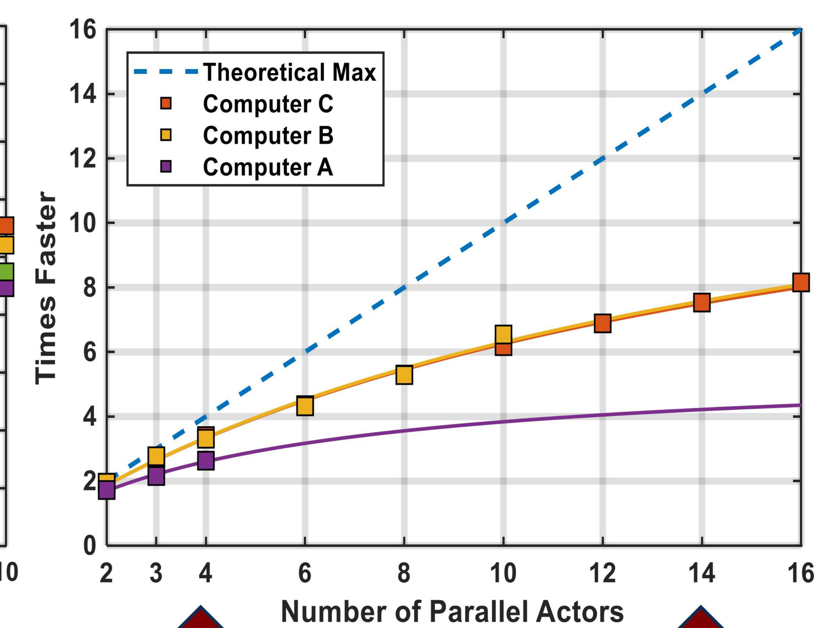


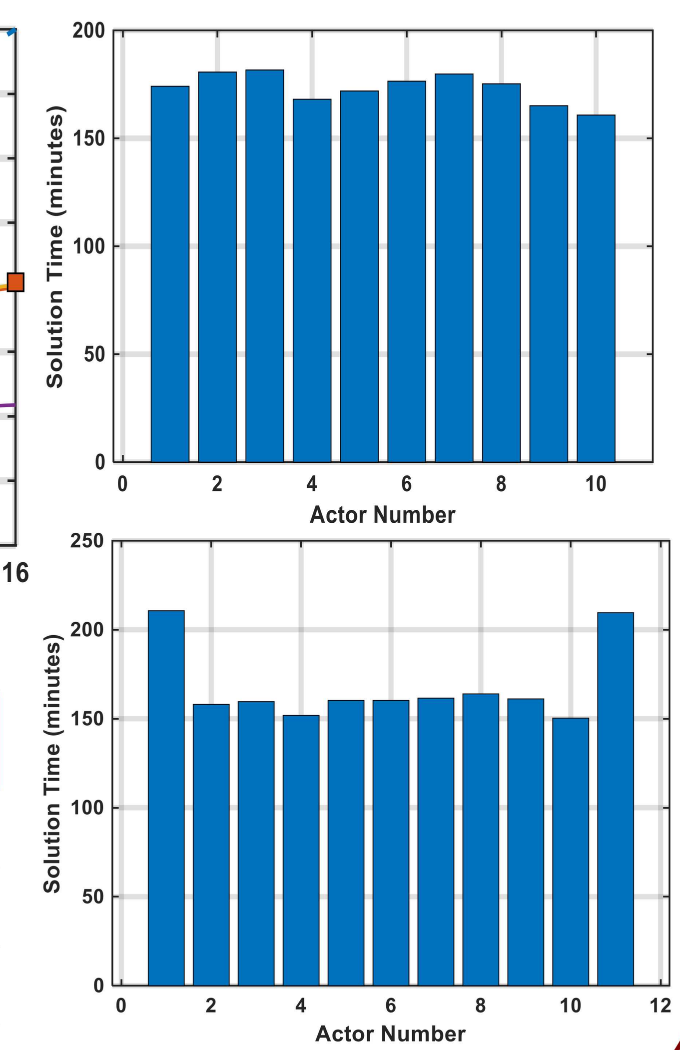


Speed Results

$$Times\ Faster = (Simulation\ Time_{base})/(\max(Simulation\ Time_{actors}))$$







Test Circuit	Times Faster (10 cores)	Amdahl Coefficient	R^2 Value
Feeder CO1	6.542x	6.52% serial	0.9887
Feeder CO1-VV	6.208x	7.09% serial	0.9928
Feeder J1	5.744x	8.48% serial	0.9896
IEEE 123	5.370x	9.40% serial	0.9974

Computer	Times Faster	Amdahl Coefficient	R2 Value
A	2.633x (4 cores)	17.84% serial	0.9894
B	6.542x (10 cores)	6.52% serial	0.9887
C	8.156x (16 cores)	6.65% serial	0.9975

Conclusions

- This paper explored the method of temporal parallelization as a solution to speed up QSTS simulations
- Four different test circuits and three different computers were used to quantify the speed improvements and accuracy of temporal parallelization
- Temporally parallelized QSTS simulations were shown to have a serial component of at least 6.52% resulting in a speed improvement of up to 8.156x faster when using 16 cores, and all errors were below thresholds
- These test circuits and the MATLAB code used to implement temporal parallelization will be publicly available: https://pvpmc.sandia.gov/pv-research/quasi-static-time-series-qsts/

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