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Parallel Differential Algebraic Equations (DAE) Solvers for Electrical Power System Transient Stability Analysis

by

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Transient Stability Analysis examines the dynamic behavior of a Power System for as much as several seconds following a power-flow disturbance. The reaction of a single generator to variations in its load can be modeled using ODEs as follows:

$$\dot{y} = f(y,z)$$

However, there are multiple generators supplying power to the network and the generators are coupled through the power network. The power network can be modeled by non-linear algebraic equations as follows:

$$0 = g(y,z)$$

and this entire system of DAE must be solved simultaneously. Transient Stability Analysis is computationally intensive because of the extremely large number of equations to be solved. The dynamics of each generator are individually modeled with as few as two and with as many as forty Ordinary Differential Equations(ODEs) while the generators are coupled via the algebraic equations that describe the electrical network. This requires the solution of large systems of simultaneous sparse non-linear equations.

Real-time or faster-than-real-time power system transient stability simulations will have significant impact on the future design and operations of both individual electrical utility companies and large interconnected power systems. Several sequential DAE solvers exist, that use various numerical techniques for solving the DAE. Prominent among these are the following:

1. LIMEX - an extrapolation integration technique [1].

2. RADAU5 - an implicit Runge-Kutta method of order 5 [2].

3. RODAS - an embedded Rosenbrock technique of order(3)4 [2].

4. SODEX - an extrapolation technique based on linearly implicit mid-point rule [2].
5. SEULEX - an extrapolation technique based on linearly implicit Euler method [2].
6. DASSL - a multistep, backward differentiation formulas technique [1].
7. LSODI - a fixed leading coefficient method using BDF technique [4, 3, 5].

But to date, there has been no explicit mention in the power system transient stability analysis literature of the application of DAE solvers. These solvers from the numerical analysis community often use higher order implicit Runge-Kutta integration techniques or Backward Differentiation Formulas (BDF) techniques that yield more accurate solutions or permit larger time-steps. DAE solvers exist that have been explicitly developed to handle discontinuities in functions – a condition encountered in transient stability calculations.

CDASSL (Concurrent Dassl) [6] is the only attempt that has been made at parallelizing these DAE solvers, as far as we know. There is enormous potential for research in this field. Our research is examining the scalability of various DAE solution techniques. Our research is concentrated on selecting the most suitable solver for the power system application, and creating a scalable library for an application based on it. The parallel version of this DAE solver will then be developed for use by the power system community, and in related applications *e.g.*[6] .

We will describe our research on the parallelization of the selected DAE solver, with reference to the power system problem. We will then present the results thus far for the parallel DAE solver using Multicomputer Toolbox [8] ; this software is currently based on the portable message-passing system *Zipcode* [7]; the Toolbox will port to MPI next year and hence our work will run on all reasonable multicomputers.

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