Coupled Electromagnetic Field & Electric Circuit Simulation: Monolithic vs. Co-Simulation Approach

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Abstract: We consider coupled dynamical systems, see [1], of the form

$$\frac{d}{dt}u(t) + b(u(t),t) = c_1(x(t)), \quad u(t_0) = u_0, \tag{13}$$

$$f\left(\frac{d}{dt}d(x(t)), x(t), t\right) = c_2(u(t)), \quad x(t_0) = x_0. \tag{14}$$

The ordinary differential equation (13) reflects the spatially discretized electromagnetic field equations, see [2]. The differential-algebraic equation (14) describes the equations of a lumped circuit obtained by the modified nodal analysis, e. g. see [3]. The vector valued time dependent functions u and x comprise the electromagnetic field and circuit system variables, respectively. The right hand side functions c_1 and c_2 describe the coupling of both systems. Notice that the systems dimension may easily reach millions of unknowns whereby the dimension of u is magnitudes higher than of x.

We discuss the advantages and limits of both, monolithic and co-simulation, approaches. Whereas the monolithic solving of (13) – (14) requires an implicit numerical solving scheme, the co-simulation approach allows (13) to be solved explicitly, e. g. using the Leapfrog integration. Considering the dimension of u as the bottleneck, an explicit solving scheme is preferred in terms of computation space and time. On the other hand c_1 and c_2 have to fulfill certain criteria in order to guarantee convergence of the co-simulation approach, contrary to the monolithic one.

For an exemplary problem with coupling functions fulfilling the sufficient criteria for the Jacobi iteration scheme derived in [4], numerical results are presented and discussed with respect to the number of iterations, speed, memory and accuracy.

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