Simultaneous switching option

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1 Introduction

The functionality of this option can be understood by looking into the EMTP solution steps:

1 Optional harmonic steady-state network solution and initialization of all state variables.
2 Send observables into the control system solver for t=0.
3 Solve the control system at t=0.
4 Advance the time-point for the next time-domain solution.
5 Update the known b part of the main set of power system equations (Ax=b).
6 Solve the network equations through a Newton method when nonlinear devices are present.
7 Send observables into the control system solver.
8 Solve the control system equations through a Newton method (optionally selected).
9 Update ideal switch type device status.
10 Update other device status.
11 Go back to step 6 when Simultaneous switching is turned-on and switch status changes or specific requests from other devices have been detected.
12 Send data to scopes.
13 Determine the solution method for the next time-point (based on discontinuity detection).
14 Update history.
15 Go back to step 4 until the maximum simulation time.

The simultaneous switching option is selected at step 10. It acts on switches as nonlinear functions and recalculates the network equations without advancing the time-point. The available options are the “Maximum number of iterations” and “Re-solve control system equations”. The simultaneous switching method in this version of EMTP is not based on a Newton method, it is a fixed-point method and the “Maximum number of iterations” represents the maximum number of switch state changes that are allowed to occur in a given time-point solution. If, for example, a cascading event requires that 2 switches are turned on one after another, then the “Maximum number of iterations” must be greater or equal to 3: 1 for the first solution and detecting the switch state change, 2 for solving the first switch state change and 3 for solving the second switch state change. It also acts as a limiter in case the switch state changes become oscillatory.

The second option “Resolve control system equations” is for optionally resolving the control system equations at step 8. This is less useful in most cases, but can be used to validate the switching conditions determined by the control system devices. This option is also used for achieving a simultaneous solution of network and control system equations as required by some device models. A given electrical network device model connected to control signals, may request to re-solve the control system equations in order to achieve a simultaneous solution, i.e. update its model equations according to the last solution of control system equations, without delay. In this case, the control system equations will be resolved even if there are no switches with status change at a given solution time-point. The “Maximum number of iterations” limits the number of iterations when specified convergence is not achieved, but there is no convergence failure message.

2 Examples

The numerical examples of this section are used to demonstrate the simultaneous switching principles. These principles can be applied in practical circuits to achieve the desired behavior.

The first simple example is shown in Figure 1. The control devices are in step mode. In a normal operation it is expected that as soon as the switch is closed, the diode must turn on and conduct since its voltage will exceed the ignition voltage. Without the “Simultaneous switching” option, there will be a one solution step delay in accounting for the controlled switch status change and another step delay for accounting the change of status in the diode. This is shown in Figure 2.

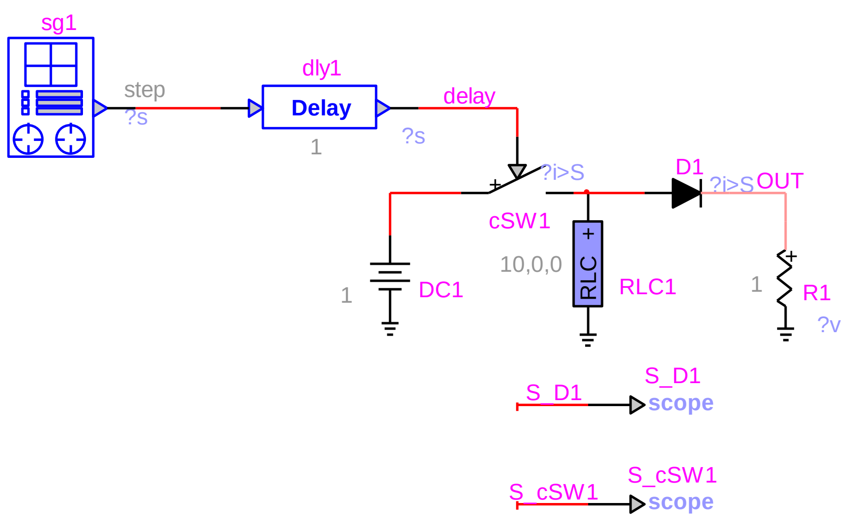

Figure 1 Test case simsw.ecf for demonstrating simultaneous switching with controls

When “Simultaneous switching” is turned on, the delay between the control signal, the controlled switch and the diode is eliminated. This is shown in Figure 3. At the time-point the delay dly1 signal is raised, the switch csW1 is closed and the diode D1 fires. The current shapes at the firing points can be considered vertical if an extra point was sent to the scopes at 1ms, as for the control signal. The same behavior is observed at current extinction. When the delay signal drops after 6ms, the switch cSW1 is opened and the diode is automatically turned off at the same time-point.

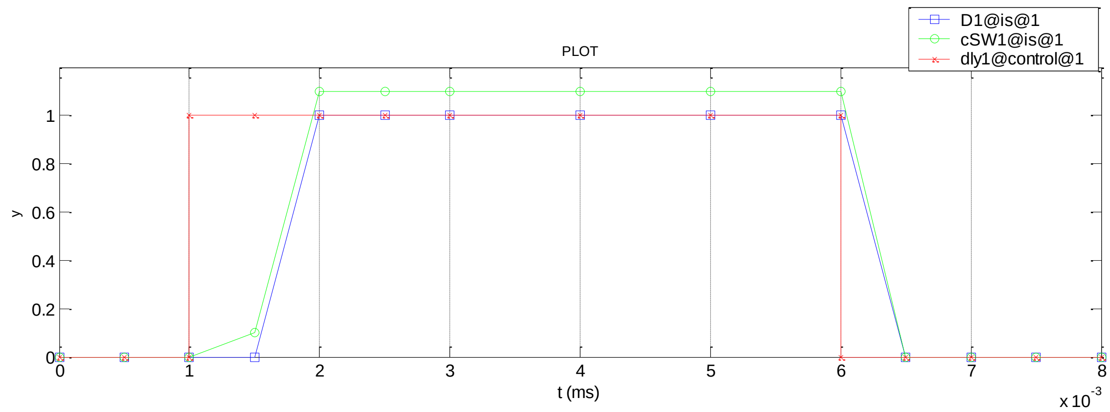

Figure 2 The switching device currents for simsw.ecf without Simultaneous switching

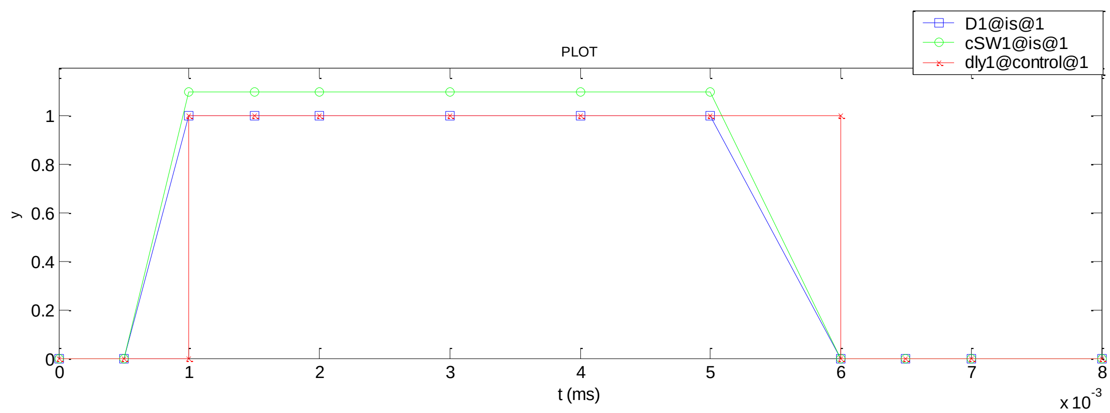

Figure 3 The switching device currents for simsw.ecf with Simultaneous switching

The second case demonstrates the significance of simultaneous switching in another diode switching case. The case is shown in Figure 4. The diodes are modeled as ideal with added fixed 0.7V voltage drop and a large reverse bias resistance. When the "Simultaneous switching" is not selected (second set of plots, @2), the diodes do not operate simultaneously. Moreover, the diode D2 conducts a negative current for one time-step. With the "Simultaneous switching" turned on, the diodes are perfectly synchronized while the inductance current remains continuous.

It is noticed that the same circuit could have been also solved without using "Simultaneous switching", but modeling the diodes with nonlinear functions (see details in the Help section of the ideal diode model).

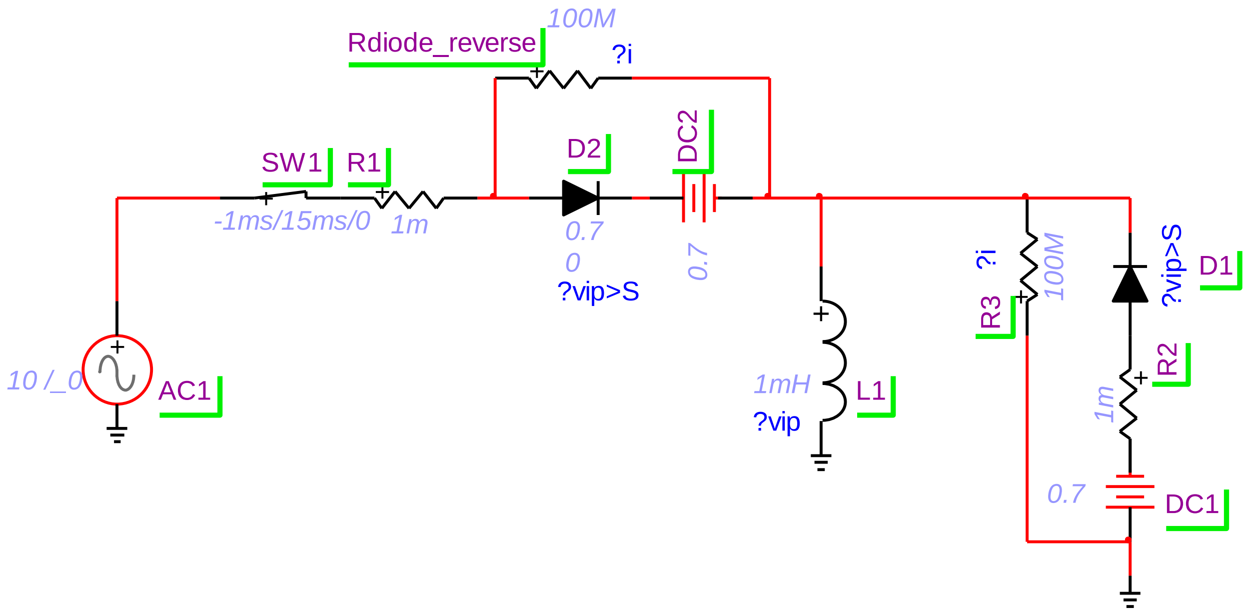

Figure 4 Simultaneous switching of diodes ([simd.ecf]())

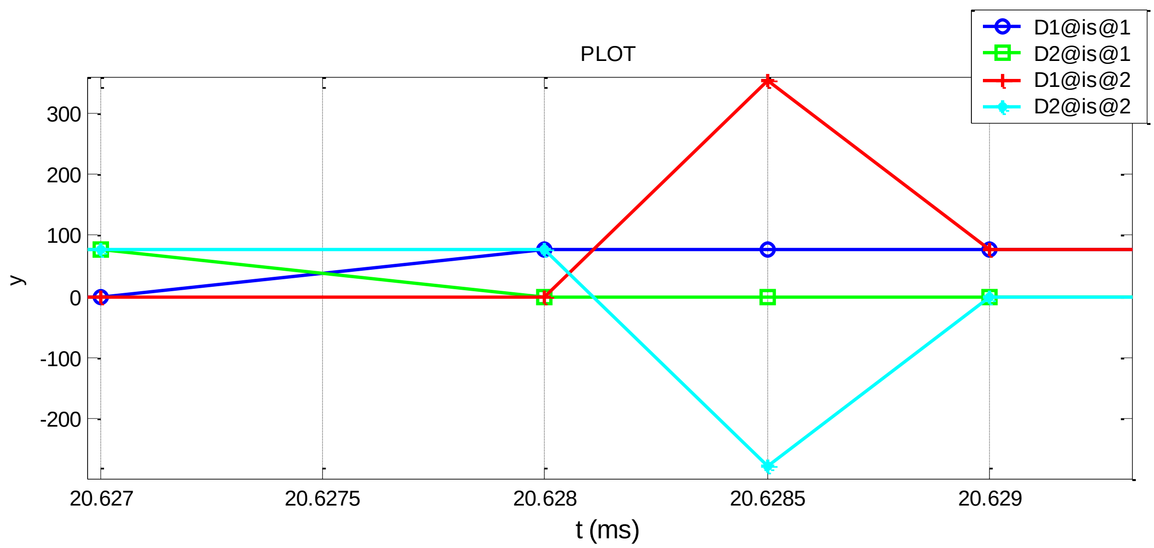

Figure 5 Diode current waveforms for simd.ecf