Systematic Simulation of Fault Behavior by Analysis of Vehicle Dynamics

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A new library for *System Reliability Analysis (SRA)* in *SimulationX* (www.simulationX.com) for systematic modelling of fault effects in multi-physical systems is introduced. The motivation is outlined, as well as a description of the library structure and two helper libraries (*FeatureExtraction*, *RequirementsFulfillment*). Additionally, an accompanying utility is presented that enables semi-automatic fault augmentation and analysis of fault-augmented models. The *SRA* library is exemplified in the automotive domain with the fault effect simulation by analysis of vehicle dynamics using a new modular library *Driving Maneuvers* in *SimulationX*, which contains various chassis model elements, wheel and axle suspensions, wheel elements with tire model, driver models, track and environment components and complete vehicle models. A vehicle model is systematically augmented with connector and component faults for the analysis of different fault effects on vehicle dynamics.

Throughout the paper, the term fault refers to any deviation from the nominal system's behavior. The Modelica® components developed for the *SRA* library in *SimulationX* simulate only the effect of a process on the system's behavior and focus on its dynamical evolution or interaction with other processes. For example, mechanical faults in joints, gears, shafts, springs or clutches because of breakage or slipping lead to the reduction of transmitted forces or torques. The current reduction because of bad or open connections in an electrical system, the mass flow decreases in a hydraulic system because of leakage or obstruction as well as changes of heat flows in a thermic system have comparable behavior and can be similarly structured, modeled and analyzed (Kolesnikov *et al*, 2018). As an example, the three oscillators from different physical domains shown in Figure 1 are similarly structured and augmented with faults in *SimulationX*. This follows from the analogies between the basic electrical, mechanical and hydraulic network elements.

In the presentation, we introduce the *SRA* and *Driving Maneuvers* libraries. Based on the developed fault-augmented vehicle model, a systematic method for the fault augmentation of multi-physical systems is outlined. In addition, we demonstrate two helper libraries and the *SRA* Add-In for semi-automatic fault augmentation, simulation analysis and post-processing of fault-augmented models.

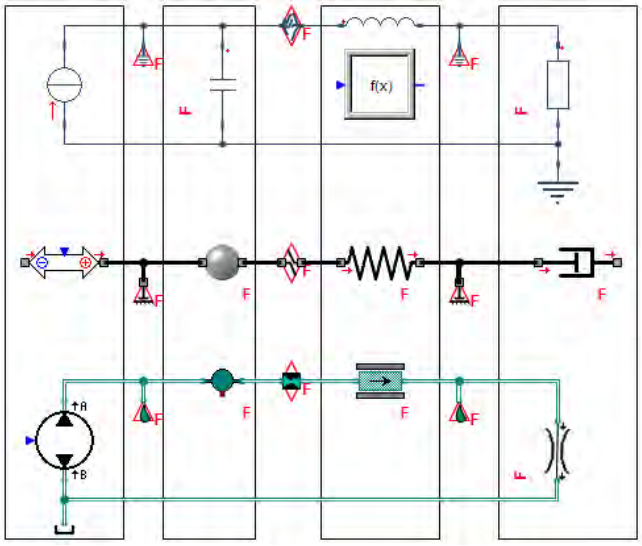

Figure 1. A model of oscillators in SimulationX with electrical, mechanical and hydraulic network elements after the augmentation with connector faults (red connectors) and parametric faults (components with the symbol F).

References

A. Kolesnikov, M. Andreev, and A. Abel. The Fault-Augmented Approach for the Systematic Simulation of Fault Behavior in Multi-Domain Systems in Aerospace. *SAE Technical Paper* 2018-01-1917, 2018, doi: 10.4271/2018-01-1917.