MpCCI-COUPLED SIMULATIONS FOR ELECTRICAL-DISTRIBUTION EQUIPMENT

Ian Lyttle, Benjamin Pulido – Schneider Electric

MOTIVATION

MpCCI has become an indispensable tool for multi-physics simulations, allowing for co-simulation using software tools native to each set of physics. Furthermore, the open architecture of MpCCI offers considerable possibilities for customization, permitting optimized solutions for specific classes of problems.

At present, MpCCI is used principally by specialists who have training and experience with MpCCI. Greater use of the tool can be made, for example, if an everyday user of thermal-analysis software can work with an everyday user of electromagnetics-analysis software to make a co-simulation, without being an everyday user of MpCCI.

Much of the co-simulation community is motivated by fluid-structure interaction (FSI) modeling, where surface regions are coupled between a fluid simulation and a structural simulation. However, at Schneider Electric we are concerned with problems where volume regions are coupled to each other. In this work, we consider problems where an electromagnetics simulation is coupled to a thermal simulation. For electrical-distribution equipment, the electromagnetics simulation calculates volume-based Joule (resistive) heating, based on temperature-dependent electrical resistivity. Accordingly, the thermal simulation calculates the volume-based temperature, based on the Joule heating.

For this work, we use FLUX (offered by Cedrat) as our electromagnetics simulation tool; we use ICEPAK or FLUENT (offered by ANSYS) as our thermal simulation tool; we use MpCCI as our coupling tool.

SOLUTION

The first step in our efforts to automate the coupling procedure was to develop a naming system (within Schneider Electric) for co-simulation. It was decided that two levels of naming are required: the class level and the scheme level.

We define a coupling class by the types of physics used. For example, the coupling class »magneto-thermal« refers to the coupling of an electromagnetics simulation with a thermal simulation. We define a coupling scheme by the broad assumptions we make within each of the physics. For the magneto-thermal example, the coupling scheme »harmonic-steady-state« identifies the electromagnetics problem as harmonic, and the thermal problem as steady-state. This class-scheme combination is abbreviated to MT-HSS.

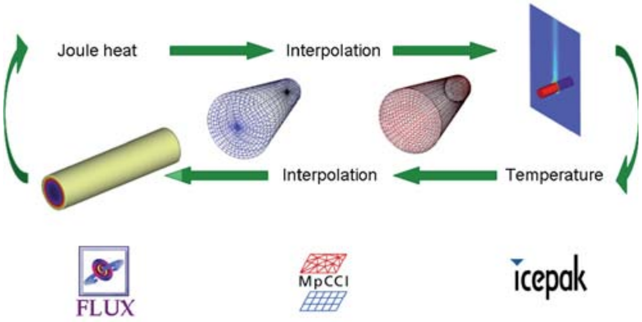

Figure 1: Flow of information for the magneto-thermal coupling class

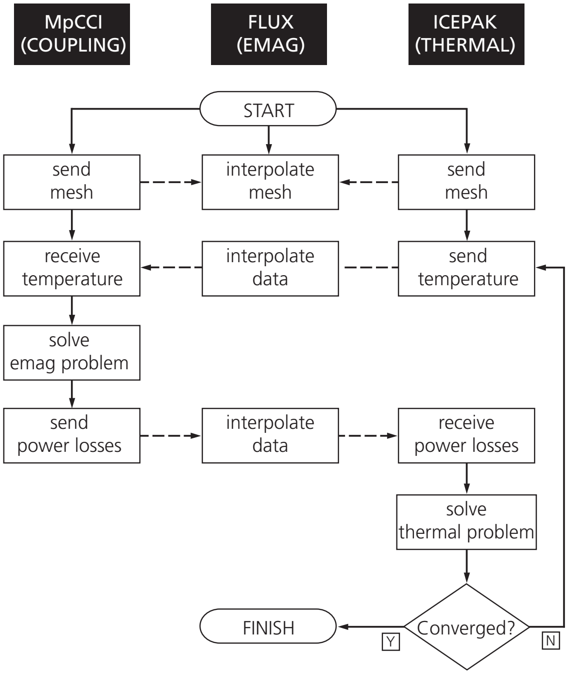

Figure 2: Simplified flowchart for the harmonic – steady-state coupling scheme

Ian Lyttle
Schneider Electric
3700 6th Street SW
Cedar Rapids, IA 52404
USA

Phone: +1 (0) 319 368-3033
ian.lyttle@us.schneider-electric.com

www.schneider-electric.com

Our next step was to define the scheme further: All co-simulations of a given scheme have the same exchange of volume data and scalar data; processes follow the same flowchart. The data flow for MT-HSS is shown graphically in Figure 1, and as a flowchart in Figure 2. From the perspective of the MpCCI project, having defined the coupling class and scheme, the only items particular to a co-simulation are the names of the simulation files and the names of the regions to be coupled.

Having established these definitions for the MT-HSS scheme, we wrote a set of scripts for FLUX and ICEPAK. To automate the construction of the MpCCI project file, we developed a simplified GUI in which the user specifies the following information:

- Coupling class, e.g. magneto-thermal
- Software, e.g. FLUX and ICEPAK
- Coupling scheme, e.g. harmonic – steady-state
- Release of simulation software, e.g. FLUX 9.3.2, ICEPAK 4.2.8
- Names of simulation files, e.g. FLUX problem, ICEPAK case
- Runtime information, e.g. amount of memory for FLUX solver

Once the coupling class and software are chosen, a tabbed window appears where the remaining choices are specified. By following a specific naming convention, a script is used to match the regions automatically. Upon the choice of coupling scheme, specific scripts used to control FLUX and FLUENT (the ICEPAK solver) are put into place. The simplified GUI constructs and saves MpCCI project file and launches the MpCCI GUI; the co-simulation is then launched from the MpCCI GUI.

By providing a simplified GUI based on the coupling class and scheme, we are able to provide everyday thermal and electromagnetics users with a reduced set of choices as compared with the MpCCI GUI. As well, we are able to automate the matching of the regions, which can save time and possibility of error. For a well-defined coupling class and scheme, this lowers considerably the threshold of MpCCI experience needed to make an effective co-simulation.

TEST CASES

Shown in Figure 3 are the results for a simple problem, where a copper wire is subjected to an alternating current. On the left of this figure are shown the electromagnetic skin-effects; on the right are shown the temperatures for the wire and the surrounding air.

We use this approach to solve problems with more-complicated geometries such as:

- Busbar systems
- Circuit breakers
- Switchboard systems

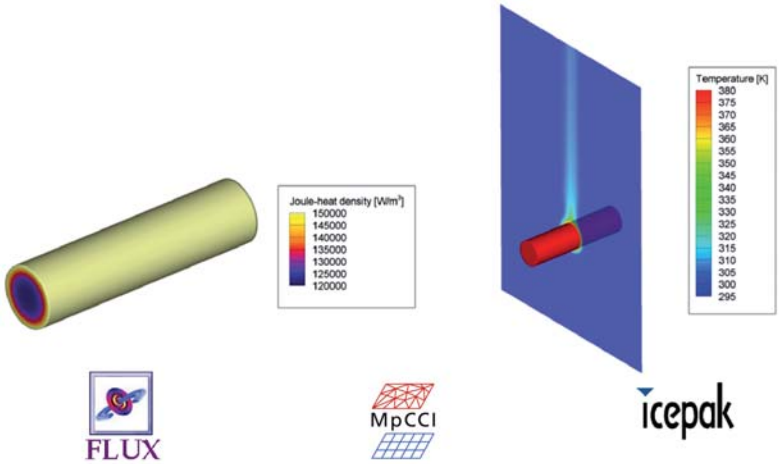

Figure 3: Results for a simple MT-HSS co-simulation

One of the features of this automation method is that the MpCCI setup for a switchboard system is no more time-consuming than for the copper-wire example. This may be notable, considering that a switchboard system may have hundreds of coupled regions, while the copper-wire has only one.

POTENTIAL IMPROVEMENTS

The developments previewed by Fraunhofer SCAI for MpCCI version 4 offer the possibilities to make more-sophisticated coupled analyses. One of these possibilities is »stronger« coupling for transient analysis; however, this depends on the partner software as well as MpCCI.

Consider the transient FSI problem using, for example, FLUENT and ANSYS. Ideally, one could choose a time-step size for FLUENT, Δt_F, according to the fluid problem and a time-step size for ANSYS, Δt_A, according to the structural problem. One could also choose an MpCCI time-step size, Δt_C, denoting the physical times for making exchanges. Presumably, the MpCCI time-step would be an integer multiple of both the FLUENT time-step and the ANSYS time-step.

A flowchart of how such a stronger coupling might be implemented is shown in Figure 4. In this arrangement, there would need to be an iterative agreement between ANSYS and FLUENT at the end of every MpCCI time-step. Within the ANSYS cycle, the loading would vary linearly with time for the MpCCI time-step. Correspondingly, within the FLUENT cycle, the displacement would vary linearly with time for the MpCCI time-step.

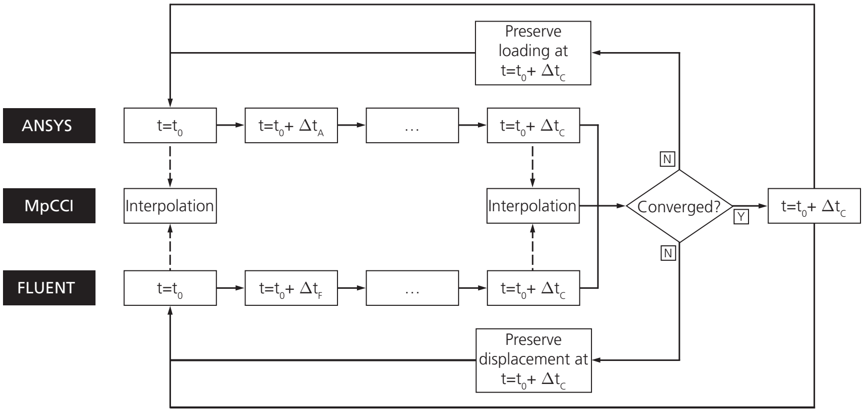

Figure 4: Outline for how »stronger« coupling might be implemented

To implement such an algorithm, it will be necessary for the partner software (FLUENT, ANSYS, etc.) to be able to save and recover their solver states at arbitrary time-steps, while maintaining their connections to MpCCI. It may be important to be able to save the solver state for an arbitrary time-step, and not just the previous time-step. This is because the user may wish for the MpCCI time-step to be a multiple of an individual software's time-step.

For those software for which this step-back procedure is not currently possible, we encourage their management and developers to work with Fraunhofer SCAI to find ways to implement this idea.

ACKNOWLEDGEMENTS

The authors would like to thank the following people and organizations for their ongoing technical support:
- Pascal Bayrasy, Fraunhofer SCAI (MpCCI)
- Rémy Perrin-Bit, Cedrat (FLUX)
- Bill Wangard, Ansys Inc. (FLUENT)
- Vincent Leconte, Schneider Electric