# **EMTP FMI Toolbox**



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Emmanuel RUTOVIC, Jerome CORNAU, 8/19/2016 11:49 AM

# 1 Description

The Functional Mock-Up Interface (FMI) is a tool-independent standard for model exchange and co-simulation. The first version, FMI 1.0, was published in 2010 [1], followed by FMI 2.0 in July 2014 [2].

EMTP is compatible with the FMI Standard for co-simulation as master (version 1.0 and version 2.0) and as slave (version 2.0 only). This document explains how to use the FMI Toolbox for EMTP.

# 2 Functional Mock-Up Interface (FMI)

The "Functional Mock-Up Interface" (FMI) is a standard initially developed by the European Consortium Modelisar. The standard specification is available for free on the official website <a href="https://www.fmi-standard.org/">https://www.fmi-standard.org/</a>.

The aim of the FMI is to standardize the data exchange between different simulation tools. The motivations for such a standard are numerous:

- No need to manually convert models from one tool to another,
- No need to manually generate and compile code,
- Relatively easy approach to parallelize and distribute computations.

The FMI standard comes in two flavors:

- **FMI for Model Exchange**: FMU (Functional Mock-Up Unit, see Figure 1) contains only the model data and equations. Compatible tools can import FMUs and use their own solver.
- **FMI for Co-simulation**: FMU contains the model data and the simulation solver (or a link towards it), see Figure 2



Figure 1: FMI for Model Exchange.



#### Figure 2: FMI for Co-Simulation.

Only control signals (integer, floating and Boolean) are exchanged.

Specifically, a FMU is a ZIP archive (with the "fmu" extension) containing:

- XML file (modelDescription.xml): for describing the model (including the number, the names and the types of inputs and outputs). The XML file format is standardized and documented in the FMI specifications.
- The model (C code or binaries): the model equations and data for the "FMI for Model Exchange" or the model data and the simulation solver (or a link towards it) for the "FMI for Co-Simulation".
- Other files required by the Slave tool.

A "Slave" tool that exports FMUs must generate a FMU that contains the files listed above. A "Master" tool that imports FMUs will have to read the FMU content and manage the exchange of data between the FMU and its calculation engine.

Tools can be compatible with one and/or the other variants of the standard and can import and/or export FMUs. The list of programs compatible with the FMI standard is available on the project website: <u>https://www.fmi-standard.org/tools</u>.

### 3 FMI Master

As explained in [2], the master program controls the data exchange between subsystems and the synchronization of all simulation solvers (slaves). With the "Master" device from the FMI library, one can load FMUs and use EMTP as FMI master program.

### 3.1 Load FMU

At first run, the user can select a new FMU file (see Figure 3). The FMU must be compatible with the FMI for co-simulation standard and must contain 32-bit Windows binaries.

Properties for Master FMI2	
pad FMU Help	
FMI Master - Load FMU	~
Select FMU file (.fmu)	
EMTP is compatible with the FMI for co-simulation standard (Versions 1 and 2).	
FNU must contain 32-dit Windows dinaries.	
	~
OK	Cancel

Figure 3: FMU Selection window.

a			$\times$
Main Data Inputs Outputs Parameters Advanced Options New FMU Help			
		1	
FMU Main Data         FMU File Name [C:\Users\eru\Desktop\Test FMU\FMI 2.0\win32\Dymola\2017\ControlledTemperature\ControlledTemperature.fmu         Model Name [C:\Users\eru\Desktop\Test FMU\FMI 2.0\win32\Dymola\2017\ControlledTemperature\ControlledTemperature.fmu         Model Name [C:\Users\eru\Desktop\Test FMU\FMI 2.0\win32\Dymola\2017\ControlledTemperature\ControlledTemperature         Generation Tool [Dymola Version 2017 (64.bit), 2016.06.23         Generation Date and Time [2016.07.05T12:36:39Z         FMI Version [2.0         Number of Inputs [0         Number of Parameters [69         FMU Simulation Options (Slave)       s         Stop Time [10.0       s			
		~	'
2	ОК	Cancel	

#### Figure 4: FMU Main Data tab.

Once the FMU is loaded, important FMU information is displayed in the "Main Data" tab (see Figure 4). One can load another FMU using the available option in the "New FMU" tab.

# 3.2 FMU Inputs and Outputs

The list of inputs and outputs is extracted from the FMU and detailed in the "Inputs" and "Outputs" tabs (see Figure 5). The Input and output bundles are automatically added to the device as shown in Figure 6.

	1		×
Ν	Aain Data   Inputs   Parameters   Advanced Options   New FMU   Help		1
	FMU Outputs		~
	Number of Outputs 2		
	Name	Description	1
	Capacitor1.i	Current flowing from pin p to pin n(Real)	
	IdealDiode3.v	Voltage drop between the two pins (= p.v - n.v)(Real)	

Figure 5: Example of Outputs tab.



### Figure 6: Example of FMU with zero input and two outputs

Four types of variable are handled by the FMI standard: String, Boolean, Integer, and Float. String variables are not processed by EMTP and will be set to "0.0" signals. For Booleans, the corresponding EMTP signal values become 1.0 for true and 0.0 for false.

### 3.3 FMU Parameters

The "Parameters" tab lists all the variables which are not inputs or outputs. The start value is the value of a variable before the first time step (initial condition). Parameters are classified in two categories (see Figure 7):

- Tunable Variables: with tunable start values,
- Non-Tunable Variables: with fixed start values.

Hence, the "start value" column of the "Parameters" tab can be modified by the user to set customized start values.

Data   Inputs   Outputs Para	meters Advanced Options New FMU Help			
MU Parameters				
Number of Tunable Va Number of Non-Tunable Va Show the Non-Tunable Vari	ariables 3 ariables 93 iables ? 🗹			
	Tunable Variables			
Name	Description	Causality / Variability	Start Value	
	Fixed size of volume 1 and volume 2 (type = Real, start = 1)	parameter / fixed	1	
V				
v m_flow_ext	Fixed mass flow rate in to volume 1 and in to volume 2 (type = Real, st	tart = 0.01) parameter / tunable	0.01	
V m_flow_ext H_flow_ext	Fixed mass flow rate in to volume 1 and in to volume 2 (type = Real, s Fixed enthalpy flow rate in to volume and in to volume 2 (type = Real, s	tart = 0.01) parameter / tunable tart = 5000) parameter / tunable	0.01 5000	
V m_flow_ext H_flow_ext	Fixed mass flow rate in to volume 1 and in to volume 2 (type = Real, st Fixed enthalpy flow rate in to volume and in to volume 2 (type = Real, s Non-Tunable Variables	tart = 0.01) parameter / tunable tart = 5000) parameter / tunable	0.01	
v m_flow_ext H_flow_ext Name	Fixed mass flow rate in to volume 1 and in to volume 2 (type = Real, st Fixed enthalpy flow rate in to volume and in to volume 2 (type = Real, s Non-Tunable Variables	tart = 0.01) parameter / tunable tart = 5000) parameter / tunable Causality / Variability	0.01 5000 Start Value	
V m_flow_ext H_flow_ext Name medium1.p	Fixed mass flow rate in to volume 1 and in to volume 2 (type = Real, st         Fixed enthalpy flow rate in to volume and in to volume 2 (type = Real, st         Non-Tunable Variables         Description         Absolute pressure of medium (type = Real, min = 0.0, max = 1000000	Causality / Variability           00.0, unit = Pa, s         local / continuous	0.01 5000 Start Value 100000.0	
V m_flow_ext H_flow_ext Name medium1.p der(medium1.p)	Fixed mass flow rate in to volume 1 and in to volume 2 (type = Real, st         Fixed enthalpy flow rate in to volume and in to volume 2 (type = Real, st         Non-Tunable Variables         Description         Absolute pressure of medium (type = Real, min = 0.0, max = 1000000         der(Absolute pressure of medium) (type = Real, min = Pa/s)	tart = 0.01) parameter / tunable tart = 5000) parameter / tunable Causality / Variability 100.0, unit = Pa, s local / continuous local / continuous	0.01 5000 Start Value 100000.0	
V m_flow_ext H_flow_ext Name medium1.p der(medium1.p) medium1.Xi[1]	Fixed mass flow rate in to volume 1 and in to volume 2 (type = Real, st         Fixed enthalpy flow rate in to volume and in to volume 2 (type = Real, st         Non-Tunable Variables         Description         Absolute pressure of medium (type = Real, min = 0.0, max = 1000000 der(Absolute pressure of medium) (type = Real, min = 0.0, max = 1000000         Structurally independent mass fractions (type = Real, min = 0.0, max = 0.0)	Causality / Variability           0.0, unit = Pa, st           local / continuous           local / continuous           10cal / continuous           10cal / continuous	0.01 5000 Start Value 100000.0 0.8	
V m_flow_ext H_flow_ext Name medium1.p der(medium1.p) medium1.Xi[1] medium1.Xi[2]	Fixed mass flow rate in to volume 1 and in to volume 2 (type = Real, st         Fixed enthalpy flow rate in to volume and in to volume 2 (type = Real, st         Non-Tunable Variables         Description         Absolute pressure of medium (type = Real, min = 0.0, max = 1000000 der(Absolute pressure of medium) (type = Real, min = 0.0, max = 5 Structurally independent mass fractions (type = Real, min = 0.0, max = 5	Causality / Variability           00.0, unit = Pa, store           local / continuous           10cal, rontinuous           10cal / continuous           10cal / contant           = 1.0, unit = 1, sta           10cal / constant	0.01 5000 Start Value 100000.0 0.8 0.2	
V m_flow_ext H_flow_ext Name medium1.p der(medium1.p) medium1.Xi[1] medium1.Xi[2] medium1.h	Fixed mass flow rate in to volume 1 and in to volume 2 (type = Real, si         Fixed enthalpy flow rate in to volume and in to volume 2 (type = Real, si         Non-Tunable Variables         Description         Absolute pressure of medium (type = Real, min = 0.0, max = 1000000 der(Absolute pressure of medium) (type = Real, unit = Pa/s)         Structurally independent mass fractions (type = Real, min = 0.0, max = Specific enthalpy of medium (type = Real, unit = Jikg)	Causality / Variability           00.0, unit = Pa, store           local / continuous           10.0, unit = 1, sta           local / constant           = 1.0, unit = 1, sta           local / constant           = 1.0, unit = 1, sta           local / constant           = 1.0, unit = 1, sta	0.01 5000 5000 5000 10000.0 0.8 0.2	
V m_flow_ext H_flow_ext Name medium1.p der(medium1.p) medium1.Xi[1] medium1.Xi[2] medium1.h der(medium1.h)	Fixed mass flow rate in to volume 1 and in to volume 2 (type = Real, si         Fixed enthalpy flow rate in to volume and in to volume 2 (type = Real, si <b>Description</b> Absolute pressure of medium (type = Real, min = 0.0, max = 1000000         der(Absolute pressure of medium) (type = Real, unit = Pa/s)         Structurally independent mass fractions (type = Real, min = 0.0, max = \$	Causality / Variability           00.0, unit = Pa, s         local / continuous           = 1.0, unit = 1, sta         local / constant           = 1.0, unit = 1, sta         local / constant           = 1.0, unit = 1, sta         local / constant           = 1.0, unit = 0, un	0.01 5000 Start Value 100000.0 0.8 0.2	
V m_flow_ext H_flow_ext Name medium1.p der(medium1.p) medium1.Xi[1] medium1.Xi[2] medium1.h der(medium1.h) medium1.d	Fixed mass flow rate in to volume 1 and in to volume 2 (type = Real, si         Fixed enthalpy flow rate in to volume and in to volume 2 (type = Real, si <b>Description</b> Absolute pressure of medium (type = Real, min = 0.0, max = 1000000 der(Absolute pressure of medium) (type = Real, unit = Pa/s)         Structurally independent mass fractions (type = Real, unit = 0.0, max = Specific enthalpy of medium (type = Real, unit = J/kg)         der(Specific enthalpy of medium (type = Real, unit = J/kg)         der(Specific enthalpy of medium (type = Real, unit = m2/s3)         Density of medium (type = Real)	Causality / Variability           00.0, unit = Pa, s         local / continuous           = 1.0, unit = 1, sta         local / constant           = 1.0, unit = 1, sta         local / constant           = 1.0, unit = 1, sta         local / continuous           = 1.0, unit = 1, sta         local / constant           = 1.0, unit = 1, sta         local / constant           = 1.0, unit = 1, sta         local / constant           = 1.0, unit = 1, sta         local / continuous           = 1.0, unit = 1, sta         local / continuous	0.01 5000 Start Value 100000.0 0.8 0.2 1000000	
V m_flow_ext H_flow_ext Name medium1.p der(medium1.p) medium1.Xi[1] medium1.Xi[2] medium1.h der(medium1.h) medium1.d der(medium1.d)	Fixed mass flow rate in to volume 1 and in to volume 2 (type = Real, si         Fixed enthalpy flow rate in to volume and in to volume 2 (type = Real, si         Won-Tunable Variables         Description         Absolute pressure of medium (type = Real, min = 0.0, max = 1000000 der(Absolute pressure of medium) (type = Real, unit = Pa/s)         Structurally independent mass fractions (type = Real, min = 0.0, max = Structurally independent mass fractions (type = Real, min = 0.0, max = Specific enthalpy of medium (type = Real, unit = J/kg)         der(Specific enthalpy of medium) (type = Real, unit = m2/s3)         Density of medium (type = Real)         der(Density of medium) (type = Real, unit = 2.5)	Causality / Variability           0.0, unit = Pa, s         local / continuous           10.0, unit = 1, sta         local / continuous           1.0, unit = 1, sta         local / constant           1.0, unit = 1, sta         local / constant           1.0, unit = 1, sta         local / continuous           1.0, unit = 1, sta         local / constant           1.0, unit = 1, sta         local / continuous	0.01 5000 Start Value 10000.0 0.8 0.2	
V m_flow_ext H_flow_ext Name medium1.p der(medium1.p) medium1.Xi[2] medium1.h der(medium1.h) medium1.d der(medium1.d) medium1.d	Fixed mass flow rate in to volume 1 and in to volume 2 (type = Real, st         Fixed enthalpy flow rate in to volume and in to volume 2 (type = Real, st         Non-Tunable Variables         Description         Absolute pressure of medium (type = Real, min = 0.0, max = 1000000 der(Absolute pressure of medium) (type = Real, min = 0.0, max = 1000000 der(Absolute pressure of medium) (type = Real, min = 0.0, max = 5 Structurally independent mass fractions (type = Real, min = 0.0, max = Specific enthalpy of medium (type = Real, unit = J/kg) der(Specific enthalpy of medium) (type = Real, unit = m2/s3) Density of medium (type = Real, unit = Pa.m-2.s) Temperature of medium (type = Real, unit = 200.0, max = 6000.0, star	Causality / Variability           0.0, unit = Pa, s         local / continuous           Iocal / continuous         local / continuous           = 1.0, unit = 1, sta         local / constant           = 1.0, unit = 1, sta         local / constant           Iocal / continuous         local / continuous	0.01 5000	

Figure 7: Tunable and Non-tunable variables.

# 3.4 FMU Advanced Options

This data tab is shown in Figure 8.

	ENULCo Simulation Conscilition (For Information Durance)	
Option	Value	
needsExecutionTool	false	
canHandleVariableCommunicationStepSize	true	
caninterpolateinputs	true	
maxOutputDerivativeOrder	0	
canRunAsynchronuously	false	
canBeInstantiatedOnlyOncePerProcess	false	
canNotUseMemoryManagementFunctions	true	
canGetAndSetFMUstate	true	
canSerializeFMUstate	true	
providesDirectionalDerivative	false	

### Figure 8: Advanced options.

The co-simulation capabilities of the FMU are listed in the "Advanced Options" tab for information purposes. For compatible FMUs (V2 Only), it is possible to create a log file in the FMU directory.

# 3.5 Practical considerations regarding time steps

Only synchronous simulations are available at the moment. It means that the master and the slaves perform their calculation sequentially and not simultaneously.

It is preferred to use the same numerical integration time-step in the master (EMTP) and in the slaves. If different time steps are used, it is strongly recommended to use a fixed ratio between the master time-step and the slave time-step ( $\Delta t_{MASTER} = k \Delta t_{FMU}$  or  $\Delta t_{FMU} = k \Delta t_{MASTER}$ , where k is a positive integer).

Since iterations in the numerical solution process are not currently part of the FMI, an artificial time-step delay is added between the master and the slaves.

### 3.6 Initialisation

As explained in [2], the FMUs enter an initialization mode before the simulation process. Values of FMU inputs at t=0 are sent to the FMU during the initialization mode. Values of FMU Outputs at t=0 are read from the FMU when it exits the initialization mode (V2 only).

This feature can be used to correctly initialize a control circuit inside a FMU from the EMTP steady-state.

# 4 FMI Slave

The Slave device from the EMTP library can be used to generate FMUs from EMTP designs. EMTP FMUs do not include the EMTP engine, hence EMTP must be installed and activated on the machine of the master tool.

# 4.1 Inputs and Outputs

It is possible to set the number of inputs and outputs in the "Main Data" tab (see Figure 9). FMU inputs are the EMTP device outputs and vice versa.

An example of resulting device is shown in Figure 10.

Properties for Slave FMI1		×
Main Data Parameters Gen	nerate FMU   Help	
FMI Slave - Generate	FMU	•
F Model Nar Number of FMU Inpu Number of FMU Outpu FMI Versi	FMU Main Data       me     MachineControl       uts     6       uts     3       ion     2.0	
	FMU Inputs (Device outputs)	
Name	Description	
Pe	Electric Power (pu)	
Omeaga_1	Machine speed (pu)	
Pmss	Steady-State Mechanical Power (pu)	
Efss	Field voltage (pu)	
vd	Stator Voltage in dq0 domain (pu)	
vq	Stator Voltage in dq0 domain (pu)	
	FMU Outputs (Device inputs)	
Name	Description	
Pm	Mechanical Power (pu)	
Ef	Electric field voltage (pu)	
t_slave	slave time (s)	
		OK Cancel

Figure 9: Main Data tab, definition of Inputs and Outputs.



### Figure 10: Example of FMI Slave device.

Custom description can be added to comment each variable.

# 4.2 Simulation options

EMTP FMU works only for time-domain solution. Hence, "Find time-domain solution" should be selected in the EMTP "Simulation options" menu.

The main time-step and the simulation time will be saved to the FMU. It is recommended that the master tool uses the same time-step and simulation time as the FMU.

### 4.3 Parameters

EMTP FMUs have four parameters (see Figure 11):

- **emtpopt.exe location**: This is the location of the emtpopt.exe file on the machine where the FMU is simulated.
- **emtpstate.ini location**: This is the location of the emtpstate.ini file on the machine where the FMU is simulated.
- **Co-simulation mode:** Two co-simulation modes are available:
  - **Mode 1 (Synchronous):** The master and the FMU perform their calculations sequentially.
  - Mode 2 (Asynchronous, same time step): The Master tool must use the same time-step as the FMU. An artificial time-step delay is added. The master and the FMU perform their calculations simultaneously.
- **Time-out (ms):** EMTP starts during the initialization mode of the master tool. It generally takes a few seconds and a time-out is allowed to elapse before an error is thrown. 5000 ms is generally sufficient, but a longer timeout might be required on some computers.

Number of Parameters 4           FMU Parameters (see documentation)           Name         Description         Start Value           emtpopt exe location         Location of the emtpopt exe file         C:\Program Files (x86)/EMTPWorks 3.3.1\EMTPlemtpopt exe           emtpstate.ini location         Location of the emtpstate.ini file         C:\Users\eru\AppDataRoaming!EMTPIC_Program_Files_x86_EMTPWorks_3_3_1temtpstate.ini           Co-simulation mode         List of available Co-simulation modes         Mode 1 (Synchronous)	IU Parameters	erate HMU   Help		 
FMU Parameters (see documentation)           Name         Description         Start Value           emtpopt.ex location         Location of the emtpopt.exe file         C:Vprogram Files (x86)/EMTPWorks 3.3.1/EMTP\emtpopt.exe           emtpstate ini location         Location of the emtpopt.exe file         C:Users\eru/uppDataRoaming/EMTPVC_Program_Files_x86_EMTPWorks_3.3_1/emtpstate.ini           Co-simulation mode         List of available Co-simulation modes         Mode 1 (Synchronous)	umber of Parameters	; [4		
Name         Description         Start Value           emtpopt.exe location         Location of the emtpopt exe file         C.'Program Files (x86)/EMTPWorks 3.3.1'EMTPhemtpopt exe           emtpotate.ini location         Location of the emtpopt.exe file         C.'Users\veruVappData\Roaming\EMTP\C_Program_Files_x86_EMTPWorks_3.3_1'emtpstate.ini           Co-simulation mode         List of available Co-simulation modes         Mode 1 (Synchronous)			FMU Parameters (see documentation)	
emtpopt.exe location of the emtpopt.exe file C:\Program Files (x86)\EMTPWorks 3.3.1\EMTPlemtpopt.exe emtpstate.ini location of the emtpstate.ini file C:\Users\eru\AppData\Roaming\EMTP\C_Program_Files_x86_EMTPWorks_3_3_1\emtpstate.ini Co-simulation mode List of available Co-simulation modes Mode 1 (Synchronous)	Name	Description	Start Value	
emtpstate.ini location d the emtpstate.ini file C:Users\eru\AppData\Roaming\EMTPIC_Program_Files_x86_EMTPWorks_3_3_1\emtpstate.ini Co-simulation mode List of available Co-simulation modes Mode 1 (Synchronous)	emtpopt.exe location	Location of the emtpopt.exe file	C:\Program Files (x86)\EMTPWorks 3.3.1\EMTP\emtpopt.exe	
Co-simulation mode List of available Co-simulation modes Mode 1 (Synchronous)	emtpstate.ini location	Location of the emtpstate.ini file	C:\Users\eru\AppData\Roaming\EMTP\C_Program_Files_x86_EMTPWorks_3_3_1\emtpstate.ini	
	Co-simulation mode	List of available Co-simulation modes	Mode 1 (Synchronous)	
Time Out (ms) Maximal time for synchronisation of the co-sit 5000	rime Out (ms)	Maximal time for synchronisation of the co-	sii 5000	

#### Figure 11: Parameters tab.

Parameters can be modified by the master tool. Default values are defined in the "Start Value" column of the "Parameters" tab in Figure 11.

The location of the emtpopt.exe and emtpstate.ini files are required by the master tool to start EMTP. Since the FMU might not be used on the computer used to create the FMU, it might be necessary to specify the location of those parameters manually.

The location of **emtpopt.exe** (EMTP computational engine) is located in *"ApplicationDir\EMTP\emtpopt.exe"*. *"ApplicationDir"* designates the application folder (path):

- a. On a 64 bit Windows system the default value is C:\Program Files (x86)\EMTPWorks.
- b. On a 32 bit Windows system the default value is C:\Program Files\EMTPWorks.

The file **emtpstate.ini** is located in "*ApplicationDataDir\emtpstate.ini*". "*ApplicationDataDir*" designates the application data folder (path):

- a) On a Windows 7, 64-bit system, the typical default value is: C:\Users\ThisUser\AppData\Roaming\EMTP\C\_Program\_Files\_x86\_EMTPWorks
- b) The following script command line can be run from a JavaScript window or code in EMTPWorks to determine application path: "writeIn(getAppDataDir);" It will output the application data path in the Script Console window

# 4.4 FMU Generation

When the EMTP design is ready, one can generate the required FMU by using the option in the "Generate FMU" tab shown in Figure 12.

Properties for Slave FMI1	×
Main Data Parameters Generate FMU Help	
FMI Slave - Generate FMU	^
Generate the FMU	
Select a FMU File Current FMU file name (it will be overwritten or created when you click OK): D:\machineControl.FMU	
Press OK to generate the FMU. FMU File name : D:\machineControl.FMU	
	×
OK	Cancel

### Figure 12: "Generate FMU" tab example.

The details of the generation process are listed in the EMTP Console. When the FMU is generated the following message is displayed.

EMTPWork	s	$\times$
À	FMU successfully generated and saved in D:\machineControl.FMU	
	ОК	

### Figure 13: FMU Generated successfully.

The generated FMU can be used on any machine where EMTP is installed and activated.

# 4.5 Compatibility and limitations

EMTP FMUs are compatible with all the tools that implement the "FMI for Co-Simulation" standard V2.0.

EMTP FMUs passe the "FMU Compliance Checker" successfully. The FMU Compliance Checker is a free software provided by the Modelica Association, implemented by Modelon AB to check a given FMU's compliance with the FMI standard. The FMU Compliance Checker can be downloaded from this link: <u>Compliance Checker</u>.

# 5 References

- [1] MODELISAR, "Functional Mock-up Interface for Co-Simulation Version 1.0," 2010.
- [2] Modelica Association Project "FMI", "FMI for Model Exchange and Co-Simulation Version 2.0," 2014.

# 6 Credits

The FMI Toolbox is based on the initial work done by Electricité de France (EDF) and uses thirdparty open-source components. You can find the source code of their open source projects along with license information below.

### Functional Mock-up Interface

The project website is: www.fmi-standard.org Copyright © 2008-2011 MODELISAR consortium, 2012-2014 Modelica Association Project "FMI" All rights reserved. Licensed by the copyright holders under the BSD 2-Clause License (http://www.opensource.org/licenses/bsd-license.html)

#### XMLWritter

XMLWriter - XML generator for Javascript, based on .NET's XMLTextWriter. Copyright (c) 2008 Ariel Flesler - aflesler(at)gmail(dot)com | <u>http://flesler.blogspot.com</u> Licensed under BSD (<u>http://www.opensource.org/licenses/bsd-license.php</u>) Date: 3/12/2008 version 1.0.0 @author Ariel Flesler http://flesler.blogspot.com/2008/03/xmlwriter-for-javascript.html

#### MiniZip

miniz.c v1.15 - public domain deflate/inflate, zlib-subset, ZIP reading/writing/appending, PNG writing