

# **Modelica by Application: Power Systems**

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**Atiyah M. G. Elsheikh & Peter Palensky**

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This release is dedicated to the first author's previous Fiancée

*Read so that you can know us   &   Write so that we can know you*

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<http://iepg.ewi.tudelft.nl/>  
<https://www.tudelft.nl/powerweb>  
<https://palensky.org/>

PP has established the CES group @ AIT. AE Joined AIT October 2011. They worked together for more than four years. This book is a resulting highlight.

## About Mathemodica.com

By the time of releasing version 1.0 of the (e-)book (September 2021), Mathemodica.com is currently a virtual organization. It currently reflects the main hobby-based (occasionally professional) activities of the first author.

One of the idea behind Mathemodica.com is to provide a transparent and a collaborative platform for those who'd like to sponsor their own ideas and works concerning Modelica-like technologies (libraries, tools, educational (e-)books, tutorials, etc.). It is desired (but not conditioned) that these activities to be in conformance with the Open Science Initiative and that the resulting products to be open-source and free.

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# Abstract

This is a comprehensive but a concise and educational (e-)book aiming at advertising Modelica-based technologies, particularly useful for power system modeling applications. Whatever aspect that could be relevantly useful has been included, to the best of the author's knowledge and time. We hope that this (e-)book is useful not only for power system modelers desiring to get a quick idea about the benefits of employing Modelica but also for those Modelica modelers desiring a starting guide into the world of Power Systems modeling applications.

## Involvement & Conditions

We hope that this book gets maintained and actualized on a regular basis. Thus, we are welcoming the idea that this e-book becomes a community-driven e-book that reflects an actualized current state of the art in Modelica based power systems modeling applications.

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- It is desired by any contribution to be valuable for educational purpose. The target scope of readers includes undergraduate students
- The target scope of reader includes non-electrical Engineers. However, instead of illustrating basic terminologies, URLs to suggested online introductory materials can be provided, cf. Section [2.1](#)
- The contents of this (e-)book is partially inspired by many academical papers, however the text is original and rewritten or enhanced in own style. In the same way, we hope provided contributions are also original.
- Similarly, it does not simply make sense to re-copy contents of an open-access paper in this (e-)book. Instead, it is more valuable to provide adequate summary in a relevant section with references to a such relevant open-access paper and/or a URL to the library implementation, cf. Chapter [9](#)
- ...

With respect to a whole chapter contribution, the following considerations are proposed:

- The purpose of a chapter contribution should be significant for the (e-)book. For instance, the purpose could include materials not covered by the book s.a. (but not limited to)
  - illustrate uncovered concepts and elements of Modelica
  - fundamental power system simulation case studies with which readers will be capable of modeling and simulating their case studies based on the provided illustration or
  - highlight distinguished aspects from relevant Modelica libraries
  - ...
- The chapters of the (e-)book are interrelated. Any additional chapter should make use of the information listed in the other chapters or even influence the contents of other chapters
- ...

## Suggested Enhancements & Open Questions

Most chapters are ended with a set of advanced open questions. A solid answer to any question may represent a valuable contribution to this (e-)book. Such an answer may demand not only in-depth understanding of the topic of the question, but also a combination between a careful literature research and creativity in composing a bigger picture from a set of disconnected pieces of information.

# Acknowledgment

We deeply acknowledge the support of our former employer AIT Austrian Institute of Technology in the development of our book. The scientific environment and innovative culture at AIT was a constant inspiration for the maturation of our ideas for this book, which started initially as a technical report. The early version was still an early outline draft until it was recently decided to re-write it as a comprehensive book.

Couple of capitals of this book has been written by others. Without their contribution, the book would be definitely less valuable. Thus, we'd like to thank (in alphabetical order of family names):

- Prof. Andrea Benigni, RWTH Aachen and Research Center Jülich, with his contribution, this book was further tuned for Electrical Engineers. Particularly, major parts of Chapter 2 and Section 11.1 were originally written by him.
- Prof. Antonello Monti, RWTH Aachen, being the initiator of the idea of having a comprehensive report that gathers all useful aspects Modelica can provide for power system modeling applications. The first chapter was originally written by him.

We'd like to acknowledge

- Markus Andres (Dassault Systéms, Lindau, Germany, V 1.0) for triggering the initiative of providing a section on relevant commercial libraries, cf. Section 9.4 and for providing us the text describing his library EPS
- Assoc. Prof. Omar Faruque (Florida State University, V 0) for presenting the initial initiative at a PES general meeting at an early phase of the drafting
- Stefan Wischhusen (XRG Simulation GmbH, Hamburg, Germany, V 1.0) for the providing a description of the Clara+ library and improving the description of the Clara library in Chapter 9

We believe that online Modelica educational materials need to be gathered together and since the idea of having a freely accessible pay-as-much-as-you-think-this-book-deserve is inspired by the author of the book "Modelica by Examples", thus, special appreciation goes to Dr. Michael Tiller, for:

- his initial agreement in hosting or linking a possible future html-based version of this book to the platform  
<https://modelica.university>
- his technical tips, recommendations and his willing to help us

Since version 0.5.2, this e-book contains URL-links to adequate materials in his book whenever more in-depth clarification of Modelica syntax could be useful for an interested

reader. In that way, the focus of this e-book remains on the application side of power systems rather than attempting to illustrate the tiniest details of the Modelica language.

We hope to have enough power in the near future to learn the technology needed to bring this book to the platform [modelica.university](http://modelica.university)<sup>1</sup>

We thank everyone who has praised us and provided positive feedback to this e-(book). However, we decided to acknowledge only those who provided a critical review with constructive precise suggestions. Thus, our appreciation goes to:

- Jan Peter Axelsson (Vascaia AB, Stockholm, Sweden, V 1.0)

We would love to have more of such useful reviews.

We also would like to thank

- Dr. Mathias Legrand for allowing to employ this wonderful latex template accessible under  
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<sup>1</sup>By the release version 0.5, We still did not invest enough time in this issue. Moreover, We are not so sure about a good way to convert/synchronize latex code to/with html. If anyone with proper technical knowledge would like to engage, (s)he is thankfully encouraged to contact us



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# Introduction

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# 1. Motivation and Outline

Original text by

**Prof. Antonello Monti (+ AE)**

Traditionally, modeling and simulation has been conducted within a **single physical domain type**. Electrical engineers used to develop electrical systems, primarily focusing on **grid modeling** and mostly neglecting other interacting domains. One of the significant exception to this rule has been a simplified representation of the rotating mass for stability analysis (Kundur et al. [1994](#); Ulbig et al. [2014](#)).

In the last decade, though, we have experienced a growing interest towards **multi-physics design** in many areas of applications. Two concrete examples of this type are the avionics industry and ship industry in relation to programs such as More Electric Aircraft (Hafez and Forsyth [2009](#); Rahrovi and Ehsani [2019](#)) and All Electric Ship (Sulligoi et al. [2016](#); Thongam et al. [2013](#)). The development of such projects has shown the limitation of the single-domain approach and has paved the way to comprehensive approaches for multi-physical modeling and simulation.

One response to the problem has been the development of **co-simulation** interfaces and standards (Blochwitz et al. [2011](#); Gomes et al. [2018](#); Müller et al. [2016](#)). Co-simulation offers the user the possibility to operate in a domain-specific environment and to relegate the integration of other simulation platforms to be mostly a software challenge.