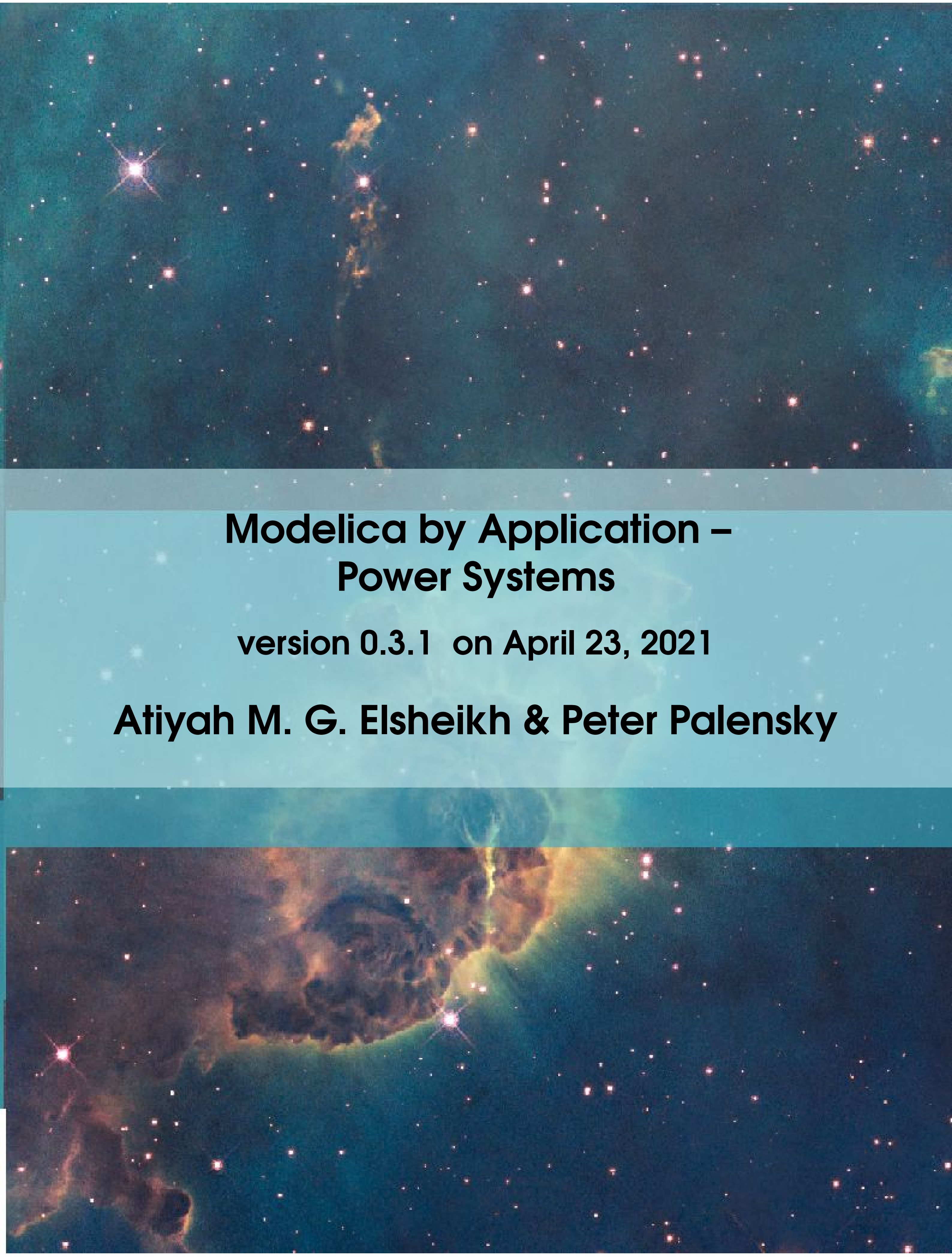

Modelica by Application – Power Systems

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Book Website:

https://github.com/Mathemodica/ModelicaPowerSystemBook

Dedication from the first author to

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About

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 useful has been included, to the best of author's knowledge. We hope that this 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 System.

Involvement & Conditions

If you are clearly involved in power-system related activities using the Modelica language, you are highly encouraged to actively improve the state of this book whenever and/or wherever possible. For this reason, this book is available on the platform Overleaf which allows collaborative writing.

However, it is important to note that, any suggested enhancement should be valuable, concise, accurate and elegant. The authors have the right to reject or to ask for specific corrections or improvements to any suggested enhancement.

Contact

Consider contacting atiyah.elsheikh@mathemodica.com if you would like to:

- contribute to the text: Consider providing a brief summary in advance of the purpose of your desired involvement
- provide suggestions or pdf-annotated review, suggested corrections, suggested text, etc.
- provide a general feedback
- provide suggested topics or materials that this book should cover
- have access to the latex sources for whatever purpose you need, e.g. project proposals, user guides, etc.

Recognition

Your useful scientific involvement, in whichever form, shall be acknowledged, unless explicitly communicated that this is not desired.

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Acknowledgment

Atiyah Elsheikh is acknowledging his former employer, Austrian Institute of Technology. This book, initially as a technical report, has been started during his role there. The early version was still in a primitive state until he recently decided to write a comprehensive book.

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

- Prof. Andrea Benigni, RWTH Aachen and Research Center Jülich, with his great help, this report is suitable for Electrical Engineers. Particularly, major parts of Chapter 2 and Section **??** were originally written by him.
- Assoc. Prof. Omar Faruque, Florida State University, for presenting this initiative at a PES general meeting
- 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.

I also would like to thank

- Dr. Mathias Legrand for allowing to employ this wonderful latex template accessible under
  https://www.latextemplates.com/template/the-legrand-orange-book

I believe that online Modelica educational materials need to be gathered together and since the idea of having a freely accessible book that is meanwhile sponsored (or to be sponsored) by any one on the basis of pay-as-much-as-you-think-this-book-deserve is inspired by the author of the book "Modelica by Examples", thus, my special appreciation goes to Dr. Michael Tiller, for:

- his initial agreement in hosting or linking a future html-version of this book to the platform
  https://modelica.university
  .
- his technical tips, recommendations and his willing to help me (despite apparently being a very busy person with his own duties)

I hope to have enough energy in near future to learn the technology needed to bring this book to the platform modelica.university and to establish url-links to adequate materials in his book whenever more in-depth clarification of Modelica syntax is needed. In that way, the focus of this book can remain on the applications side of power systems rather than attempting to illustrate the tiniest details of the Modelica language.

Contents

I

Motivation

1. Motivation and Outline

Original text by

Prof. Antonello Monti (Enhanced by 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 [139, 222].

In the last decade though, we have experienced a growing interest towards multi-physics design in many different 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 [108, 192] and All Electric Ship [216, 219]. 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 [28, 103, 166]. 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.

While this approach has some clear advantages from user perspective, first of all the possibility to continue operating with the same tools also in the new operating conditions, co-simulation tends to have a significant computation and implementation overhead given by the co-presence of more than one simulation platform. Nevertheless, many tools exist simplifying the co-simulation implementation overhead, e.g. [169, 234].

Furthermore, it is quite easy to face versioning issue created by the fact that the project as a whole is stored in multiple files. There are also so many technical issues that goes beyond this text.

Proposition 1.1 In summary, one day co-simulation will be most effective if it converges to the state that a modeler is neither aware nor technically caring that his descriptive models are executed via co-simulation.

Consequently there is a growing interest towards multi-physical modeling languages. Multi-domain languages provide an interesting solution, majorly because they are languages and not simulation platforms.

This means that the modeling effort and the solution effort are clearly separated. This separation brings an incredible benefit from the user point of view that is able to migrate from one simulation tool to another without repeating the modeling effort.

Proposition 1.2 Converting from a tool user to a model designer via a well-designed modeling language extends the horizon of realizable applications to an extent that is beyond imagination.

There are many simulation languages of this type available s.a. VHDL-AMS[12], gPROMS [106] and Modelica [72]. The last language has been developed as an initiation for a standard modeling language used by a large modeling community in many modeling domains. This has resulted in an open-source non-property specification language continuously maintained, supported and progressed both from academia and industry.

Outline of this book

The outline of the book is structured as follows. In Part I we first review the major challenges in power system modeling and simulation. These demonstrates new requirements for modeling and simulation tools for modern power system modeling applications. In order to appreciate the evolution process of such modern modeling languages, we reveal how the accumulation of progressive milestones along many decades led to the concepts on which current state of the art of modeling language are based on.

In Part III, we dive into the Modelica language, giving a non-familiar reader though rather a compact overview of the language but hopefully generous enough to recognize its potentials in the scope of power system modeling applications. This demonstration is based on one of the existing and elegant open-source libraries. This particular library provides the opportunity to demonstrate many syntactical and significant features of the Modelica language.

In Part III we overview current state of the Modelica language. Particularly, we summarize

- language specification, the underlying process of its development through the Modelica association
- the Modelica Standard Library and some of its major components significant for power system modeling,
- the functional mockup interface including related projects
- as well as other significant related topics that may matter the reader

Furthermore, reflecting our humble struggle to eliminate the thirst of a knowledge seeker, we provide a comprehensive list of open-source Modelica libraries in the field of (and in many areas related to) power systems. The list includes libraries in the field of energy in buildings and cities as well as other fundamental methodological libraries, e.g. for generating statistical distributions or for imitating a hybrid paradigm.

Finally, since power systems models are naturally large-scale, in Part IV we demonstrate current challenges facing the Modelica language addressed together with recently and actually conducted research efforts for overcoming these challenges. We summarize with a list of benefits the Modelica language can offer in the context of modern power system modeling applications. We overview a list of potential extensions to the Modelica language in order to enable further capabilities, e.g. partial differential equations or prototyping of simulation-optimization problems.