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SmarTS Lab
Smart Transmission Systems Laboratory

# Modeling power systems with Modelica using *OpenIPSL*

## A Modelica Library for Power System Simulation


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Tutorial

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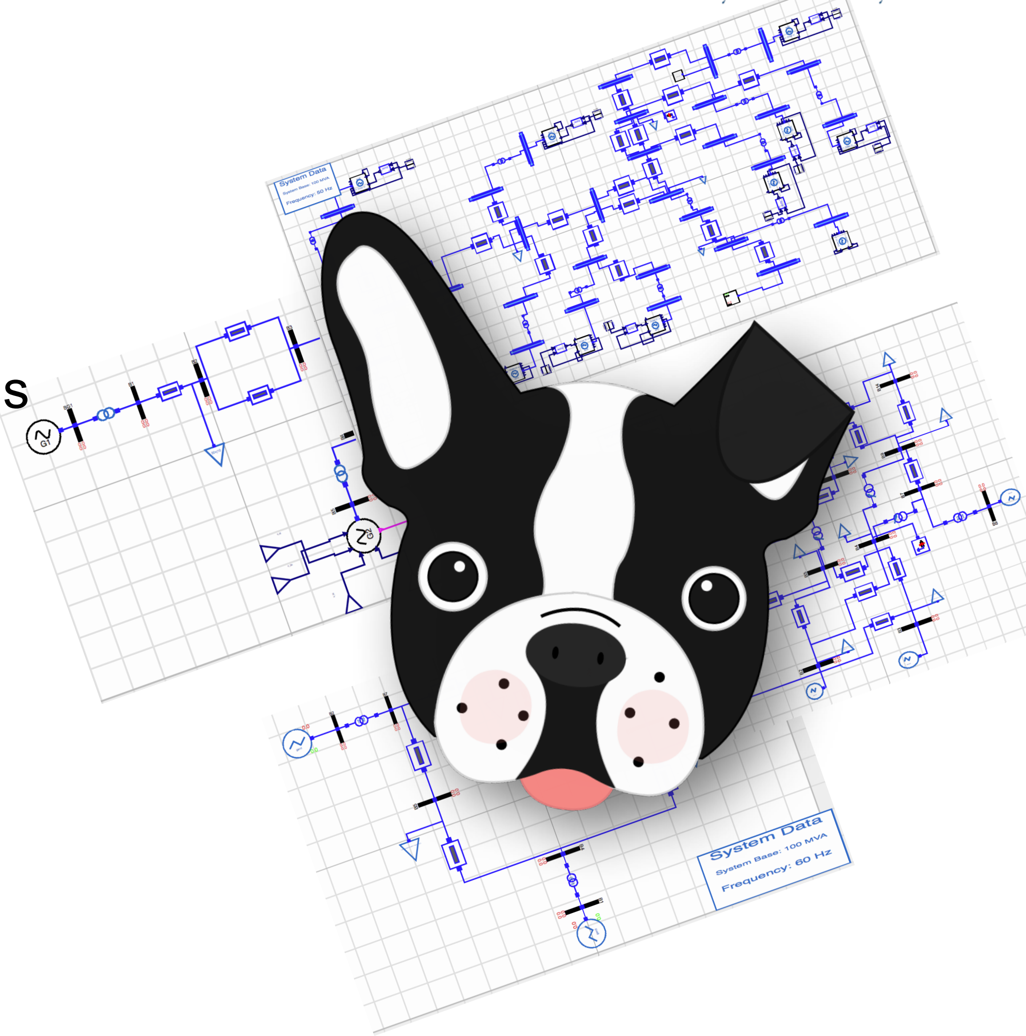
www.modelica.org

# Outline

- Generalities and the role of models and simulation
- Modelica and power systems
- OpenIPSL
- Project documentation
- On-going developments



# The Underlying Question:

Why do we develop models and perform simulations?

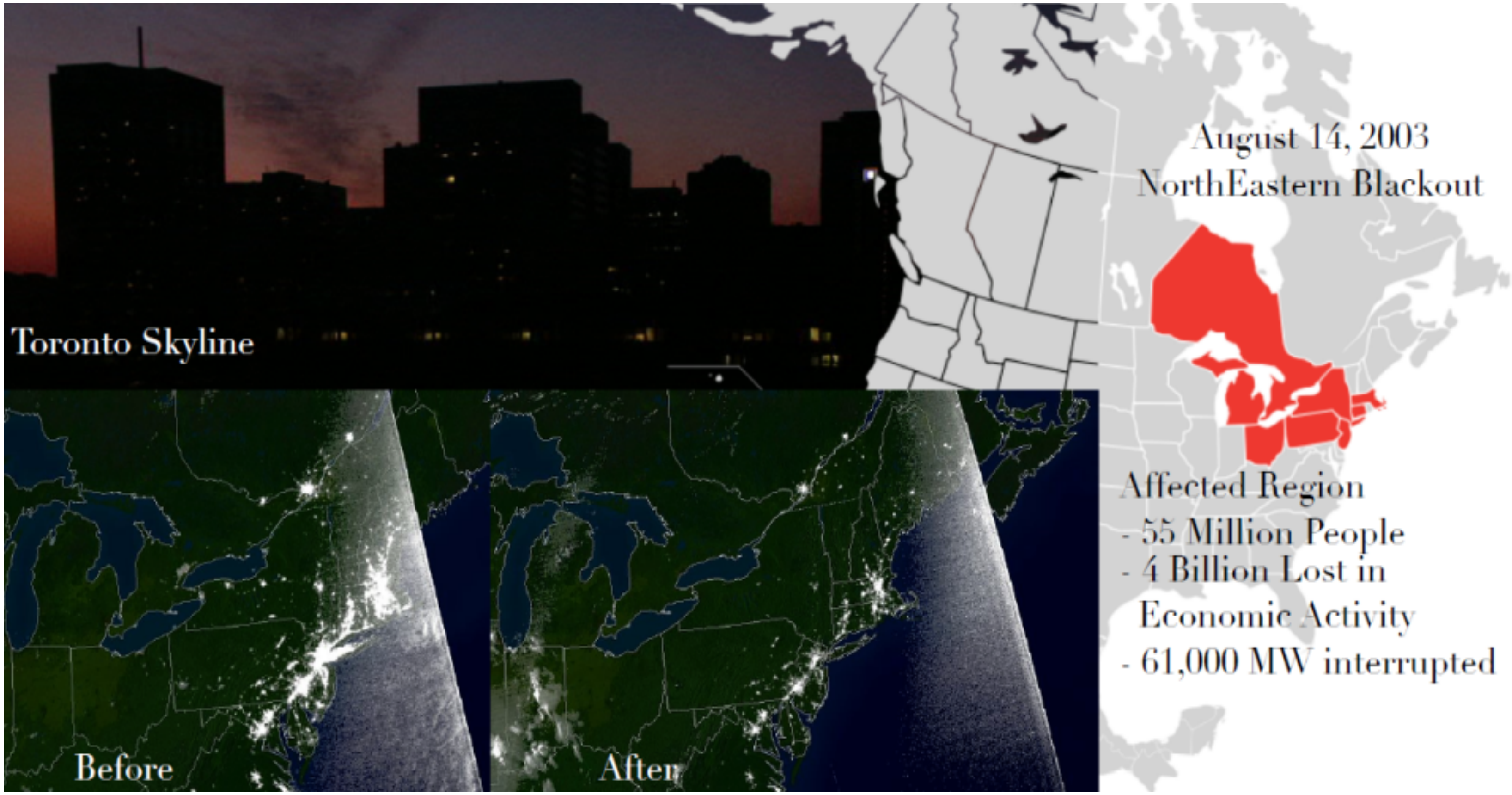
To reduce the lifetime cost of a system

- *In requirements:* trade-off studies
- *In test and design:* fewer proto-types
- *In training:* avoid accidents
- ***In operation:* anticipate problems**

- The prospective pilot sat in the top section of this device and was required to line up a reference bar with the horizon. 1910.
- More than half the pilots who died in WW1 were killed in training.

# A **Failure** to Anticipate → Huge Costs!

There are many examples of failures to anticipate problems in power system operation




**Others:** WECC 1996 Break-up, European Blackout (4-Nov.-2006), London (28-Aug-2003), Italy (28-Sep.-2003), Denmark/Sweden (23-Sep.-2003)

**Failure!:** Existing modeling and simulation (and associated) tools were unable to predict these events.

# **The Multiple Roles** of Modeling and Simulation
# in building Complex Cyber-Physical ”Systems-of-Systems”

# Simulating Success

How do modeling and simulation activities, capabilities benefit Boeing? Let us count the ways—9 of them

By Debby Arkell

Hands-on experience often can be the best way to tackle complex problems or master challenging skills. But when it comes to navigating intricate, variable-laden scenarios, or combat situations involving complex military maneuvers using expensive equipment, “on-the-job training” often is not a prudent approach.

That's why Boeing Integrated Defense Systems, Commercial Airplanes and Phantom Works engage in a wide variety of modeling and simulation activities, designed to provide ever more realistic simulations to internal customers across the enterprise—and to external customers as well.

“There is a tremendous amount of diversity in modeling and simulation being worked on at Boeing, encompassing very complex issues within a very broad spectrum,” said Ron Fuchs, director of Modeling and Simulation for IDS. “Right now there are more than

Boeing analysts have a variety of tools available—or under development—that can demonstrate concepts and provide significant cost savings by exploring ideas, developing systems, testing and manufacturing within a virtual environment before committing to specific approaches.

## 4 Product or system testing

Models and simulations are used to test

M&S used to test prototypes in variety of environments.

networked computer systems in the FCS system of systems will be tested in a large-scale distributed simulation facility called the FCS System of Systems Integration Lab. The SoSIL provides a

## 6 Training systems and maintenance

M&S are used to *train users in the operational environment* – enhancing learning. Simulation *costs 1/10* of running actual scenarios.

## Network communications

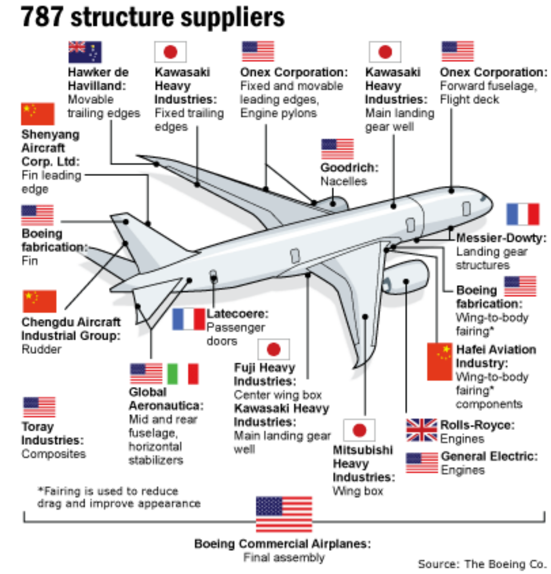
Tactical military communications networks—such as Joint

Scale of networks: cost-prohibitive or technically impossible for field tests.

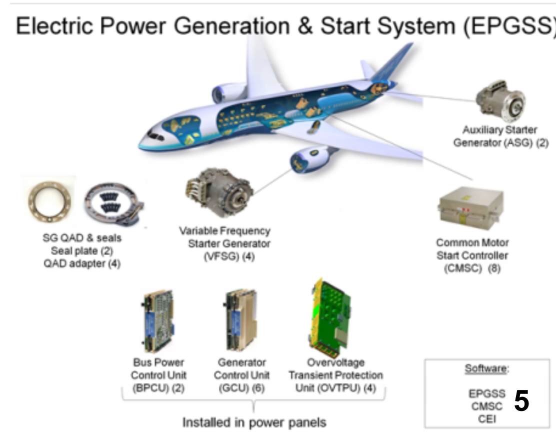
M&S used to test and validate networking protocols in laboratory - environment acting as a test bed.

8 ... is an environment that acts as a distributed virtual test bed, and the Boeing Transformational Communications Laboratory in El Segundo, Calif., performs a similar function for satellite communications.

Large Number of Vendors for the Final System

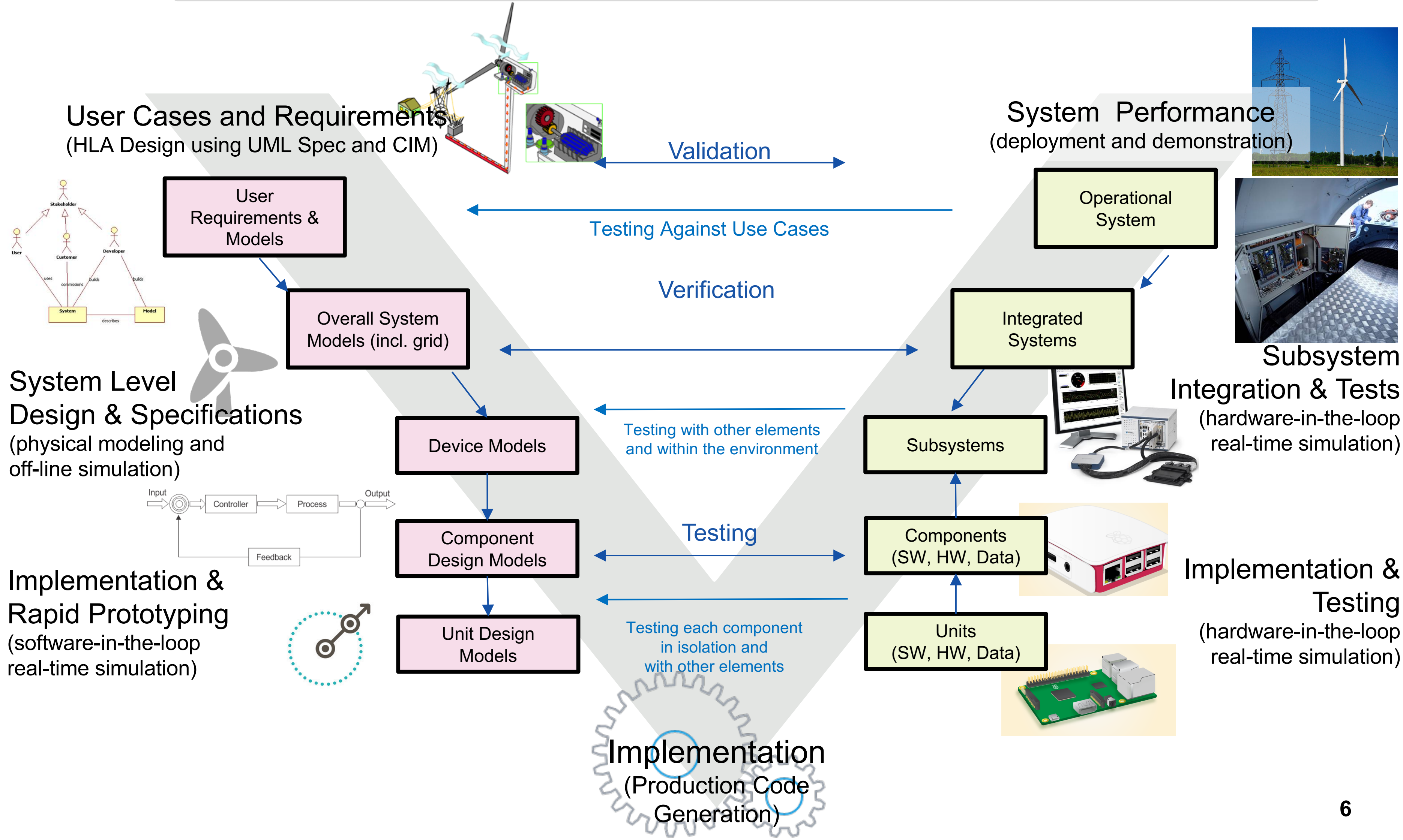



A Flying Micro-Grid!



# **The Multiple Roles** of Modeling and Simulation in building the future Cyber-Physical Power Systems (aka ‘smart grids’)

Conceptual Application for the Development of a WT Synchro phasor-Based Controller



# Dangers of Models and Simulation

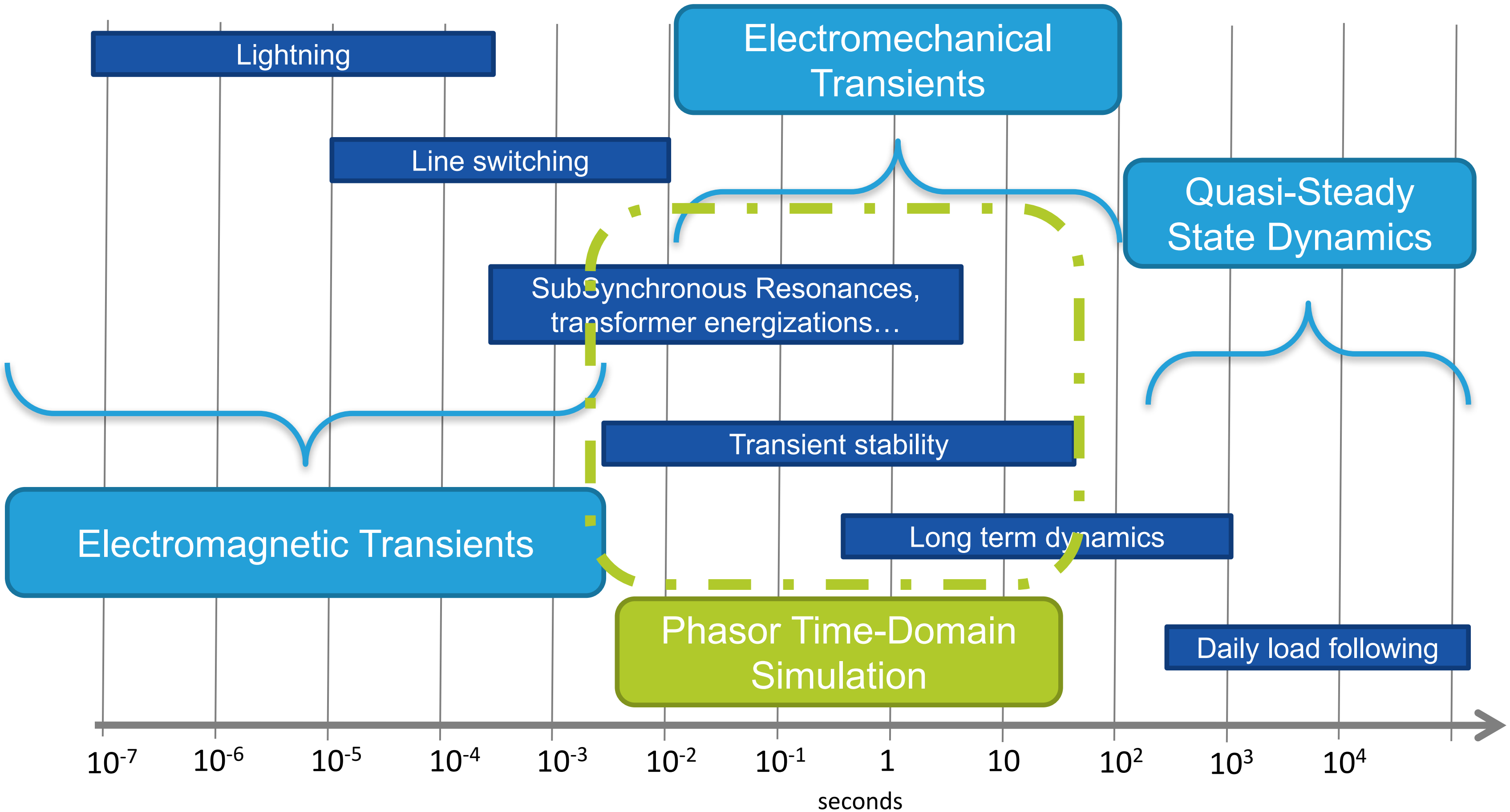
- **Falling in love with a model**
  The Pygmalion effect (forgetting that model is not the real world)
  - From the Greek myth of Pygmalion, a sculptor who fell in love with a statue he had carved.

- **Forcing reality into the constraints of a model**
  The Procrustes effect (e.g. economic theories)
  - Procrustes: "the stretcher [who hammers out the metal]", a rogue smith from Attica that physically attacked people by cutting/stretching their legs, so as to force them to fit the size of an iron bed.
  - A **Procrustean bed** is an **arbitrary standard** to which exact conformity is forced.

- **Forgetting the model's level of accuracy**
  Simplifying assumptions forgotten more than yesterday's pudding…

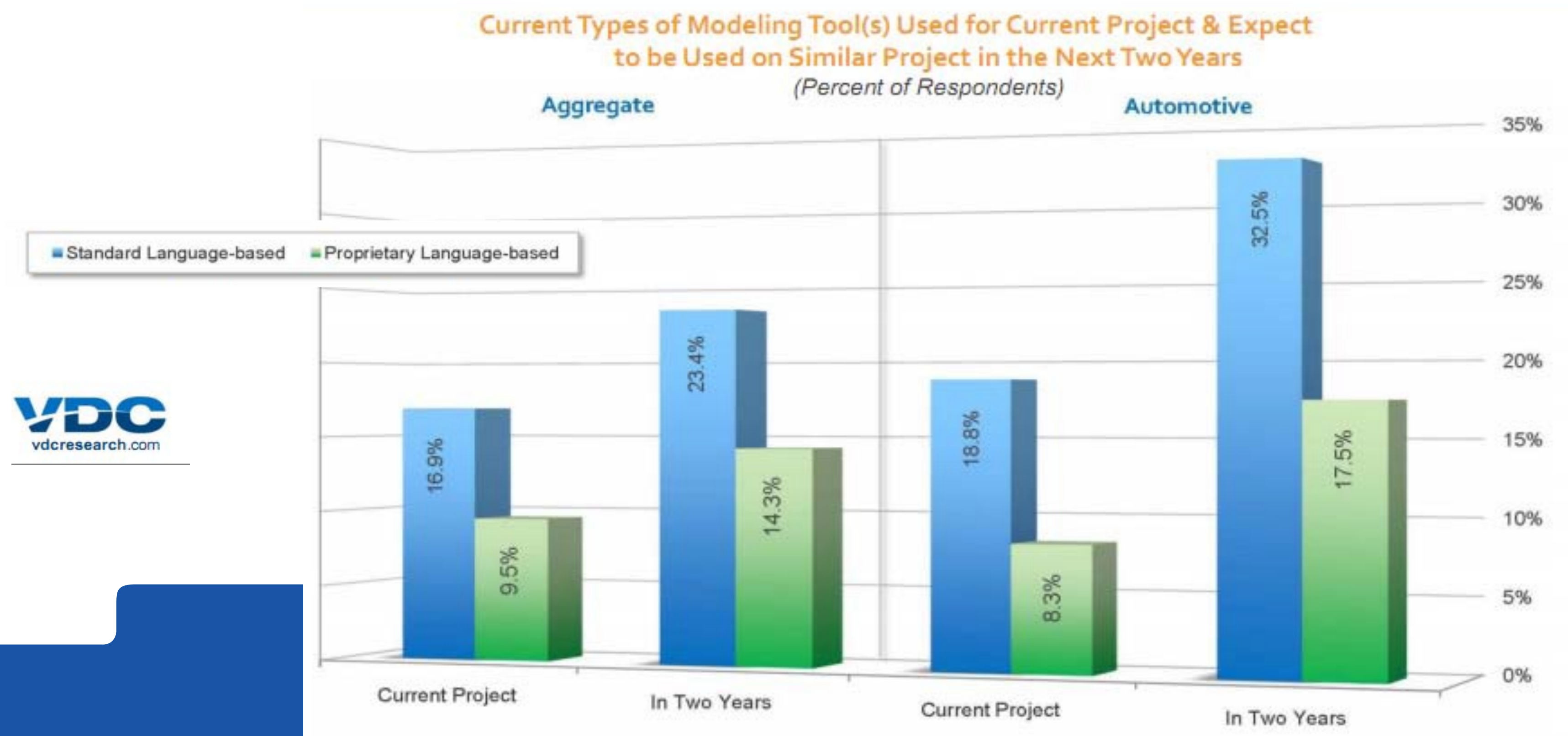
# Phenomena modeled from this point on:

## power system *electromechanical dynamics*

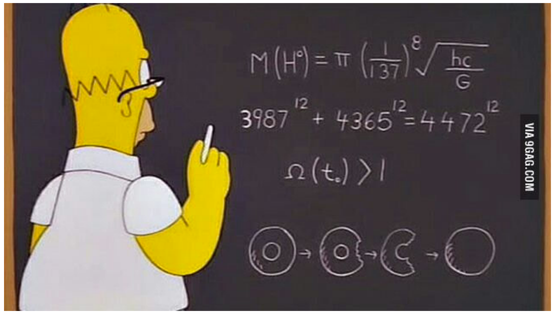


# Why (open)-standardized modeling languages?

- Modeling tools first gained adoption as engineers looked for ways to simplify SW development and documentation.
- **Today's modeling tools and their use cases have evolved.**
- ***Now:*** need for addressing both system level design and SW development/construction.



# Why equation-based modeling?




- Defines an implicit relation between variables.
  - **The data-flow between variables is defined right before simulation** of the model (not during the modelling process!)
- A system can be seen as a complete model or a set of individual components.
- **The user is (in principle) only concerned with the model creation, and does not have to deal with the underlying simulation engine (only if desired).**
- It also allows decomposing complex systems into simple sub-models easier to understand, share and reuse

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MODELICA

**is a (computer) language, is not a tool!**

- Modelica is a free/*libre* object-oriented modeling language with a textual definition to describe physical systems using differential, algebraic and discrete equations.
- A Modelica modeling environment is needed to edit or to browse a Modelica model graphically in form of a composition diagram (= schematic).
- A Modelica translator is needed to transform a Modelica model into a form (usually C-code) which can be simulated by standard tools.
- A Modelica modeling and simulation environment provides both of the functionalities above, in addition to auxiliary features (e.g. plotting)

MODELICA

**Modelica® - A Unified Object-Oriented Language for Systems Modeling**

**Language Specification**

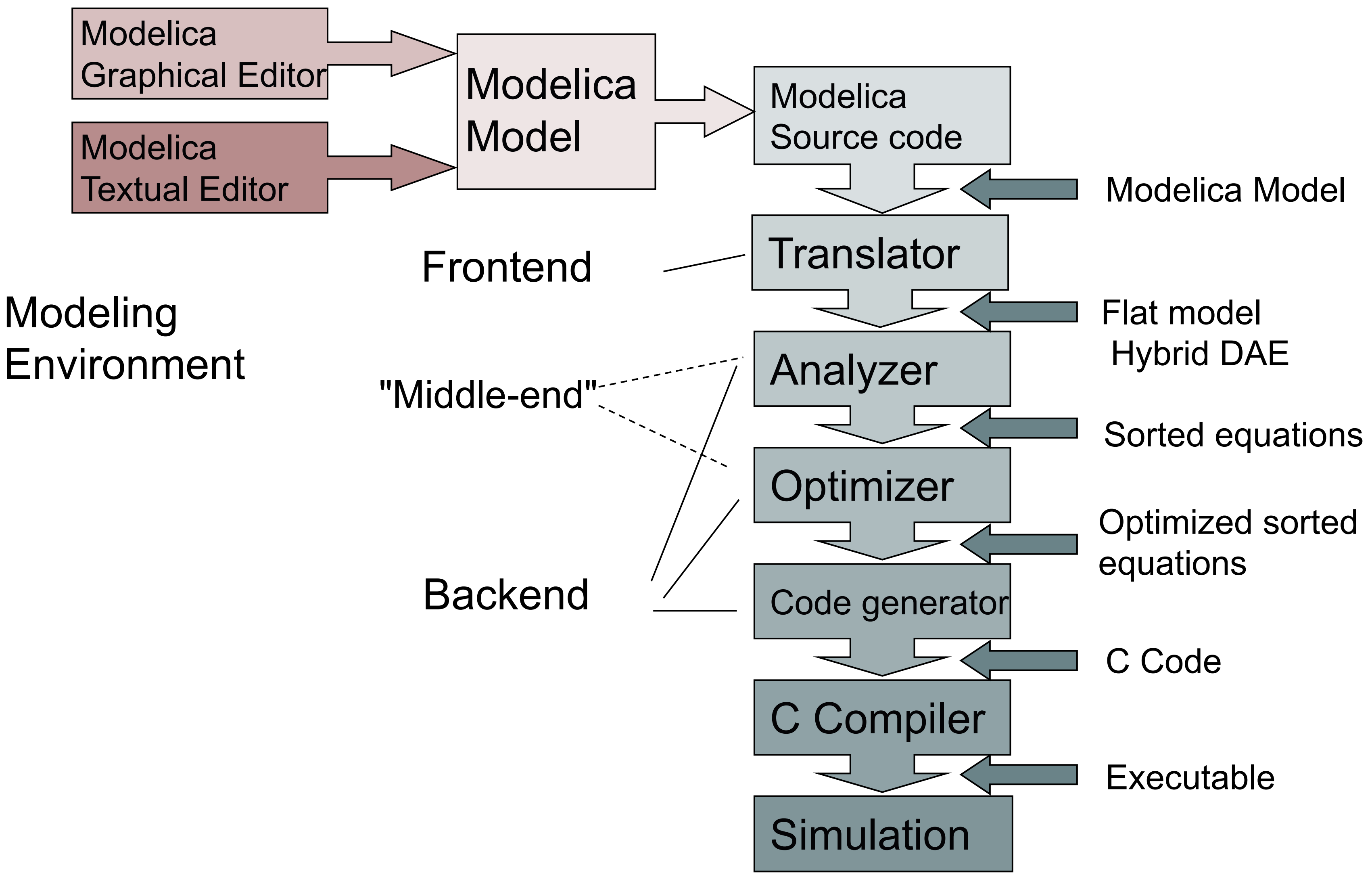
**Version 3.3 Revision 1**

July 11, 2014

http://modelica.readthedocs.io/en/latest/#

***Key: standardized and open language*** specification

# Modelica modeling and simulation environment tasks



# Why MODELICA power systems?

- The **order of computations** **is decided at modelling time**

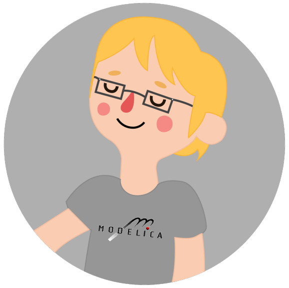
| Acausal | Causal |
| --- | --- |
| `R*I = v;` | `i := v/R;`<br>`v := R*i;`<br>`R := v/i;` |

- Most tools make **no difference between "solver" and "model"** – in many cases solver is implanted in the model

- There is **no guarantee** that the same standardized model is implemented in the same way across different tools
- Even in Common Information Model (CIM) v15, **only block diagrams** are provided instead of equations

- Models are **black boxes** whose parameters are shared in a **specific "data format"**
- For large models this **requires translation** into the internal data format of each program

# MODELICA and Power Systems



## Previous and Related Efforts

- Modelica for power systems *was first attempted* in the early 2000’s (Wiesmann & Bachmann, Modelica 2000) - “electro-magnetic transient (EMT) modeling” approach.
  - SPOT (Weissman, EPL-Modelon) and its close relative PowerSystems (Franke, 2014); supports multiple modeling approaches –i.e. 3phase, steady-state, “transient stability”, etc.
- Electro-mechanical modeling or “transient stability” modeling:
  - Involves electro-mechanical dynamics, and neglects (very) fast transients
  - For system-wide analysis, easier to simulate/analyze - domain specific tools approach
- ObjectStab (Larsson, 2002; Winkler, 2015) adopts ”transient stability” modeling.
- The PEGASE EU project (2011) developed a small library of components in Scilab, which where ported to proper Modelica in the FP7 iTesla project (2012-2016).
- The iPSL - iTesla Power Systems Library (Vanfretti et al, Modelica 2014, SoftwareX 2016), was released during 2015. Most models validated against typical power system tools.

**OpenIPSL takes iPSL as a starting point and moves it forward (this presentation).**

- F. Casella (OpenModelica 2016, Modelica 2017) presents the challenges of dealing with large power networks using Modelica, and a dedicated library to investigate them using the Open Modelica compiler.

# MODELICA and Power Systems

## Why another library for power systems?

- Why not use one of the existing Modelica projects?
  - *There is no technical argument:* in principle, either SPOT, PowerSystems, or ObjecStab could have been used instead of creating a new library (iPSL, and OpenIPSL)

## Social Aspects (Vanfretti et al, Modelica 2014):

- Resistance to change: an irrational and dysfunctional reaction of users (and developers?)
  - Users of conventional power system tools are skeptical about any other tools different to the one they use (or develop), and are averse about new technologies (slow on the uptake)
- Change agents contribute (+/-) to address resistance through actions and interactions:
  - ***Strategy:*** do not impose the use of a specific simulation environment (software tool), *instead*,
  - Propose a **common human and computer-readable mathematical "description":** use of Modelica for unambiguous model exchange.
- Decrease of avoidance forces:
  - SW-to-SW validation gives quantitatively an similar answer than domain specific tools.
  - Accuracy (w.r.t. to *de* facto tools) more important than performance

## A never-ending effort:

- Our (my) goal has been to bridge the gap between the Modelica and power systems community by
  - Addressing resistance to change (see above)
  - Interacting with both communities – different levels of success…

# The *OpenIPSL* Project

- **KTH SmarTS Lab** (my research team) actively participated in the group or partners developing iPSL until the end of the ***iTesla*** project (March 2016)
- **iPSL** is a nice prototype, ***but we identified the following issues:***
  - **Development:** Need for compatibility with OpenModelica, (better) use of object orientation and `proper use of the Modelica language features.`
  - **Maintenance:** Poor harmonization, lack of code factorization, etc.
  - **Human issues:** The development workflow was complex, because of
    - Different parties with disparate objectives, levels of knowledge, philosophy, etc.

New research requirements and the experiences from previous effort indicated:
- a clear *need for a different development approach* –
**one** that should address a complex development & maintenance workflow!

- OpenIPSL *started as a **fork*** of iPSL
- OpenIPSL is hosted on GitHub at https://github.com/SmarTS-Lab/OpenIPSL
- OpenIPSL is actively developed by SmarTS Lab members and friends, as a research and education oriented library for power systems
  → ***it is ok to try things out*** !

***Fork:*** copy of a project going *in a different development direction*

OpenIPSL

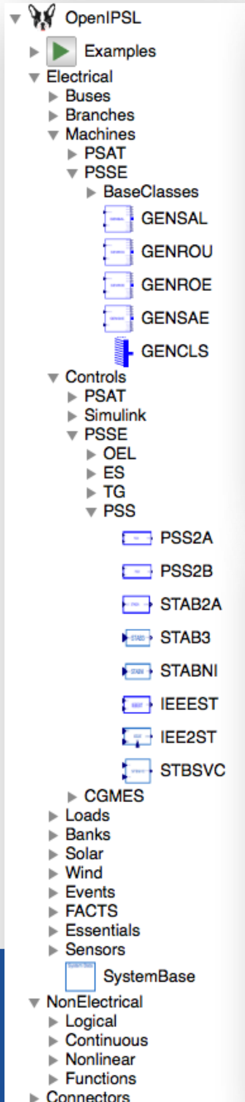
# The *OpenIPSL* Library

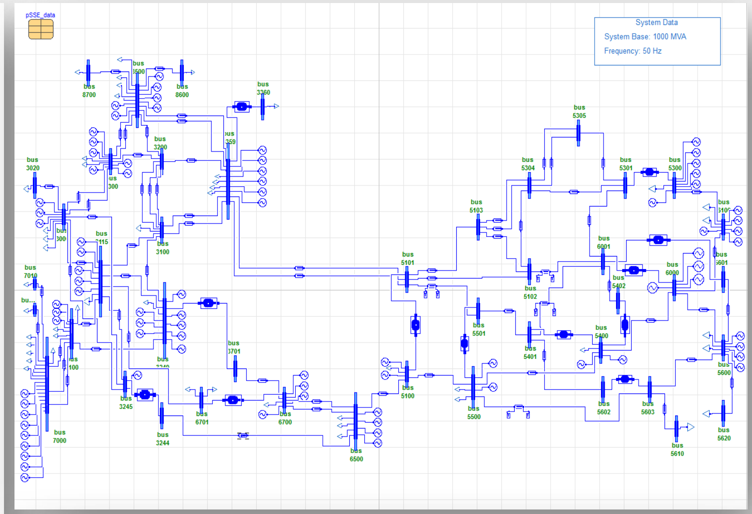
**OpenIPSL** is an open-source Modelica library for power systems

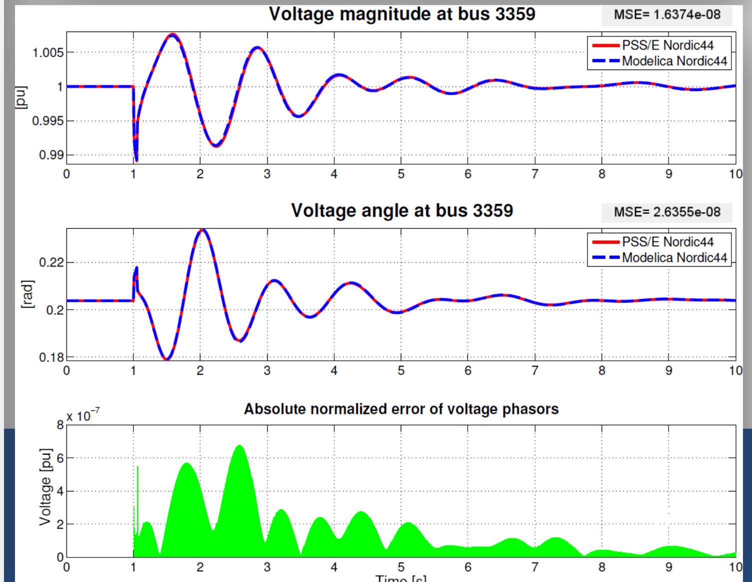
- It contains a set of **power system components** for **phasor time domain** modeling and simulation
- Models have been **validated** against a number of reference tools

**OpenIPSL** enables:

- **Unambiguous** model exchange
- Formal **mathematical description** of models
- **Separation** of **models** from IDEs and **solvers**
- Use of **object-oriented** paradigms

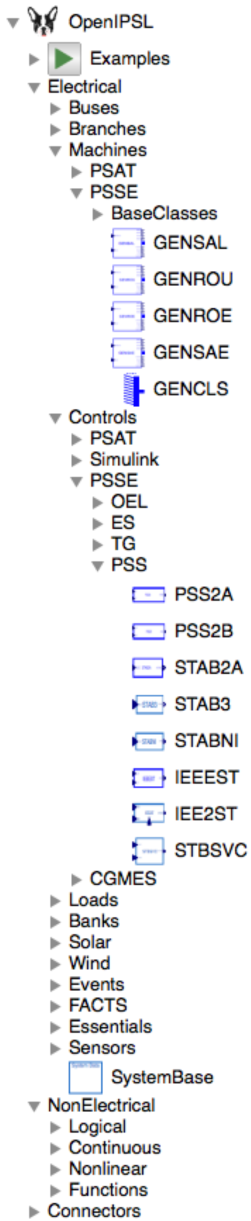


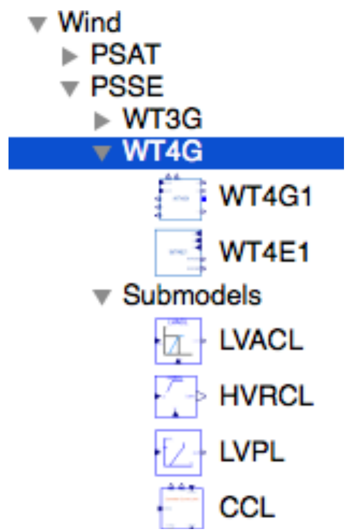



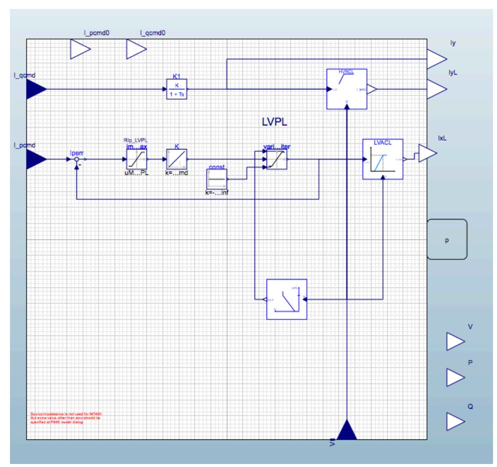



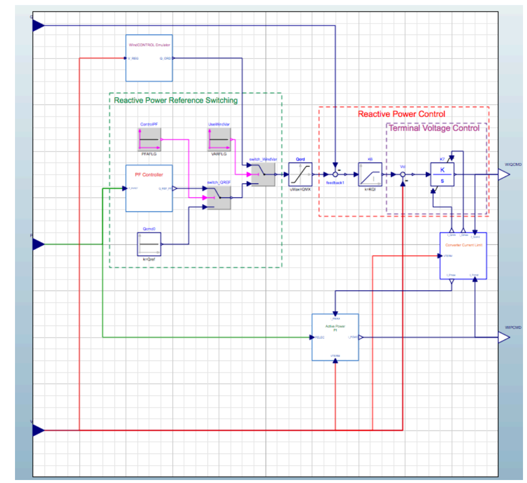
# The *OpenIPSL* Library – WT Example

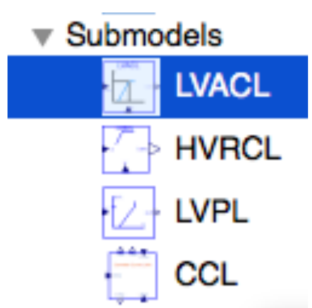
OpenIPSL

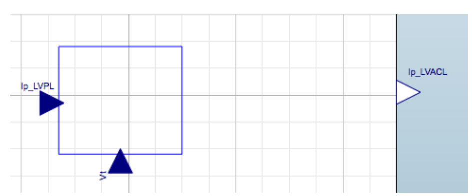


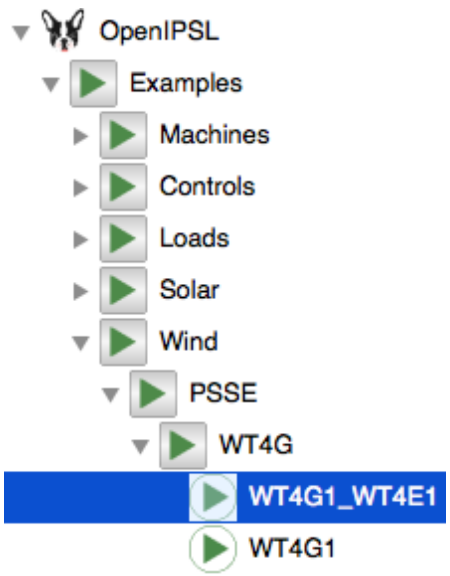



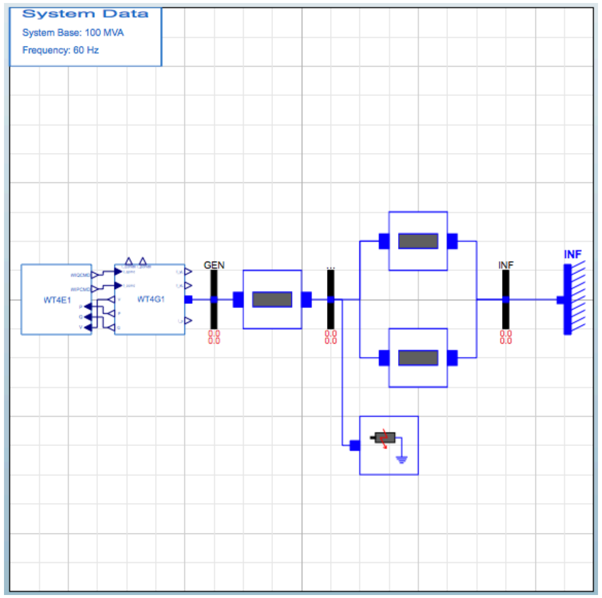




```
model LVACL
  //The Low Voltage Active Current Management block is de
  //of active power under very low voltage scenarios. Thi
  //  The protection function is activated when
  //the terminal voltage drops below 0.8 pu and stranglin
  //0.4 pu. For voltages between 0.8 pu and 0.4 pu to red
  Modelica.Blocks.Interfaces.RealOutput Ip_LVACL ¤;
  Modelica.Blocks.Interfaces.RealInput Vt ¤;
  Modelica.Blocks.Interfaces.RealInput Ip_LVPL ¤;
equation
  if Vt < 0.4 then
    Ip_LVACL = 0;
  elseif Vt > 0.8 then
    Ip_LVACL = Ip_LVPL;
  else
    Ip_LVACL = Ip_LVPL * 1.25 * Vt;
  end if;
  ¤;
end LVACL;
```

# The *OpenIPSL* Library – Network Example

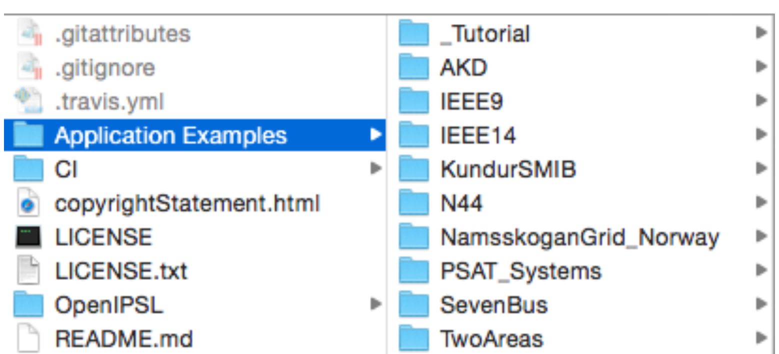
OpenIPSL




```
model WT4G1_WT4E1
  extends Modelica.Icons.Example;
  constant Real pi = Modelica.Constants.pi;
  parameter Real V1 = 1.0;
  parameter Real A1 = -1.570655e-05;
  parameter Real V3 = 0.9999999000000001;
  parameter Real A3 = 0.02574992;
  parameter Real P1 = -1.4988;
  parameter Real Q1 = -4.334;
  parameter Real Zr = 0.0;
  parameter Real Zi = 0.2;
  parameter Real P3 = 1.5;
  parameter Real Q3 = -5.6658;
  parameter Real R1 = 0.025;
  parameter Real X1 = 0.025;
  parameter Real B1 = 0.05;
  parameter Real dyrw[1, 9] = [0.02, 0.02,
  OpenIPSL.Electrical.Branches.PwLine pwLin
  OpenIPSL.Electrical.Branches.PwLine pwLin
  OpenIPSL.Electrical.Machines.PSSE.GENCLS
  OpenIPSL.Electrical.Branches.PwLine pwLin
  OpenIPSL.Electrical.Wind.PSSE.WT4G.WT4G1
  OpenIPSL.Electrical.Events.PwFault pwFaul
  OpenIPSL.Electrical.Wind.PSSE.WT4G.WT4E1
  inner OpenIPSL.Electrical.SystemBase SysD
  OpenIPSL.Electrical.Buses.Bus GEN ;
  OpenIPSL.Electrical.Buses.Bus BUS1 ;
  OpenIPSL.Electrical.Buses.Bus INF ;
equation
  connect(wT4G1.p, GEN.p) ;
  connect(GEN.p, pwLine2.p) ;
  connect(pwLine2.n, BUS1.p) ;
  connect(BUS1.p, pwLine.p) ;
  connect(pwLine1.p, pwLine.p) ;
  connect(pwFault.p, BUS1.p) ;
  connect(pwLine.n, INF.p) ;
  connect(pwLine1.n, INF.p) ;
  connect(INF.p, gENCLS2_1.p) ;
  connect(wT4E1_1.WIQCMD, wT4G1.I_qcmd) ;
  connect(wT4E1_1.WIPCMD, wT4G1.I_pcmd) ;
  connect(wT4G1.P, wT4E1_1.P) ;
  connect(wT4G1.V, wT4E1_1.V) ;
  connect(wT4G1.Q, wT4E1_1.Q) ;
  ;
end WT4G1_WT4E1;
```

**Many Application Examples Developed!!!**



# Initialization (1/3) - General DAE Model

$$\dot{\mathbf{x}} = f\left(\mathbf{x}, \mathbf{y}, \boldsymbol{\eta}, \tilde{\mathbf{u}}, t\right),$$

$$\mathbf{0} = g\left(\mathbf{x}, \mathbf{y}, \boldsymbol{\eta}, \tilde{\mathbf{u}}, t\right).$$

$\mathbf{x}$ – is the vector of state variables, $\mathbf{x} = \tilde{\boldsymbol{\xi}}_i$

$\mathbf{y}$ – is the vector of algebraic variables, $\mathbf{y} = \tilde{\boldsymbol{\xi}}_f$

$\boldsymbol{\eta}$ – is the vector of parameters, from discarding $\tilde{\varphi}_s$ and letting $\tilde{\boldsymbol{\xi}}_s = \boldsymbol{\eta}$

$\tilde{\mathbf{u}}$ – is the vector of discrete variables.

$f(\cdot)$ – are the differential equations, $f(\cdot) \equiv \tilde{\varphi}_i(\cdot)$

$g(\cdot)$ – are the algebraic equations, $g(\cdot) \equiv \tilde{\varphi}_f(\cdot)$



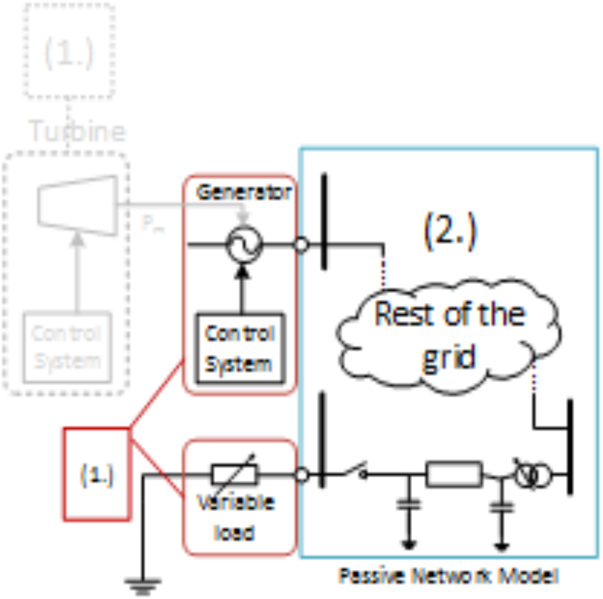
[Ref.] F. Milano, Power System Modeling and Scripting, Springer, 2010.

# Initialization (2/3) - Power System Approach

- Equation set ***g*** is separated in two sets of algebraic equations:

$$\left.\begin{aligned} \dot{\mathbf{x}} &= f\left(\mathbf{x},\mathbf{y},\boldsymbol{\eta},\tilde{\mathbf{u}}\right), \\ \mathbf{0} &= g_1\left(\mathbf{x},\mathbf{y},\boldsymbol{\eta},\tilde{\mathbf{u}}\right), \end{aligned}\right\} \quad (1.)$$

$$\mathbf{0} = g_2\left(\mathbf{y},\boldsymbol{\eta},\tilde{\mathbf{u}}\right)\} \quad (2.)$$




(1) Is the part which governs how dynamic models will evolve, since they depend on both **x** and **y** , e.g. generators and their control systems.

(2) Is the network model, consisting of transmission lines and other passive components which only depends on algebraic variables, **y**

# Initialization (3/3) – Differences

- The power system needs to be at rest, i.e. its states must have converged to a fixed point before a disturbance is applied in simulation, that is **x(0) = C**
  - Q: How can we find this equilibrium for a DAE system?
  - A: Set derivatives to zero and solve for all unknown variables!

$$\mathbf{0} = f\left(\mathbf{x}, \mathbf{y}, \boldsymbol{\eta}, \tilde{\mathbf{u}}, t\right),$$
$$\mathbf{0} = g\left(\mathbf{x}, \mathbf{y}, \boldsymbol{\eta}, \tilde{\mathbf{u}}, t\right).$$

Modelica –compliant tools attempt to solve this problem!

- Some observations that can be made:
  - The algebraic equations in corresponded to having the fast differential equations at equilibrium all the time (in the model and in the timescale considered).
  - Finding the equilibrium when most of the variables are unknown is very difficult if when we try to solve this equation system simultaneously.
- Power system tools do not do this (to the best of my knowledge)!
  - In power systems, we attempt to sequentially solve the equation system at *t=0.*
  - First, we need to solve the algebraic equations *g* that only depend on the algebraic variables… and then solve *f=0.*

# The *OpenIPSL* – “initial guess” approach

OpenIPSL

- **An initial guess for all algebraic, continuous and discrete variables need to be provided to solve a `numerical problem!`**
- When solving differential equations, one needs to provide the **initial value** of the state variables at rest.

- In Modelica, **initial values can be either solved or specified** in many ways, we use the following
  - Using the ”initial equation” construct:

```
initial equation
     x = some_value OR x = expression to solve
```

  - Setting the (*`fixed=true, start=x0`*) attribute when instantiating a model, will
  - If nothing is specified, the default would be a guess value (*`start= 0, fixed=false`*).

- In the OpenIPSL models we do the following:
  - The initial guess value is set with (*`fixed = false`*) for initialization.
  - Model attributes are treated as parameters with value (*`fixed = true`*),

- In OpenIPSL we use a power flow solution from an external tool (e.g. PSAT or PSS/E) as a starting point to compute initial guess values through parameters within each model.
  - The power flow solution is NOT the initial guess value itself.
  - Aim is to provide a better “initial guess” to find the initial values of the DAE system.

# The *OpenIPSL* – "initial guess" example

## Third order model from PSAT implemented in OpenIPSL

OpenIPSL

Power flow data

| | |
|---|---|
| V_b | 400 |
| V_0 | 1 |
| angle_0 | 0 |
| P_0 | 1 |
| Q_0 | 0 |
| S_b | SysData.S_b |
| fn | SysData.fn |

Base voltage of the bus (kV)

Initialization

| | | | |
|---|---|---|---|
| w | 1 | | Rotor speed (pu) |
| v | V_0 | true | Generator terminal voltage (pu) |
| P | P_0 / S_b | | Active power (pu) |
| Q | Q_0 / S_b | | Reactive power (pu) |
| anglev | angle_0 / 180 * pi | | Bus voltage angle |
| e1q | e1q0 | | q-axis transient voltage (pu) |

```
model Order3 "Third Order Synchronous Machine with Inputs and Outputs"
  import Modelica.Constants.pi;
  extends BaseClasses.baseMachine(delta(start = delta0), pe(start = pm00), pm(start = pm00)

    Real e1q(start = e1q0) "q-axis transient voltage (pu)";
  protected
    parameter Real Xd = xd * CoB "d-axis reactance, p.u.";
    parameter Real x1d = xd1 * CoB "d-axis transient reactance, p.u.";
    parameter Real Xq = xq * CoB "q-axis reactance, p.u.";
    parameter Real m = M / CoB2 "Machanical starting time (2H), kWs/kVA";
    parameter Real c1 = Ra * K "CONSTANT";
    parameter Real c2 = x1d * K "CONSTANT";
    parameter Real c3 = Xq * K " CONSTANT";
    parameter Real K = 1 / (Ra * Ra + Xq * x1d) "CONSTANT";
    parameter Real delta0 = atan2(vi0 + Ra * ii0 + Xq * ir0, vr0 + Ra * ir0 - Xq * ii0) "Initialitation";
    parameter Real vd0 = vr0 * cos(pi / 2 - delta0) - vi0 * sin(pi / 2 - delta0) "Initialitation";
    parameter Real vq0 = vr0 * sin(pi / 2 - delta0) + vi0 * cos(pi / 2 - delta0) "Initialitation";
    parameter Real id0 = ir0 * cos(pi / 2 - delta0) - ii0 * sin(pi / 2 - delta0) "Initialitation";
    parameter Real iq0 = ir0 * sin(pi / 2 - delta0) + ii0 * cos(pi / 2 - delta0) "Initialitation";
    parameter Real pm00 = (vq0 + Ra * iq0) * iq0 + (vd0 + Ra * id0) * id0 "Initialitation";
    parameter Real vf00 = e1q0 + (Xd - x1d) * id0 "Initialitation";
    parameter Real e1q0 = vq0 + Ra * iq0 + x1d * id0 "Initialitation";
  initial equation
    der(e1q) = 0;
  equation
    der(e1q) = ((-e1q) - (Xd - x1d) * id + vf) / Td10;
```

# The *OpenIPSL* Project Documentation

OpenIPSL

The intention is to have comprehensive documentation in the repositories:

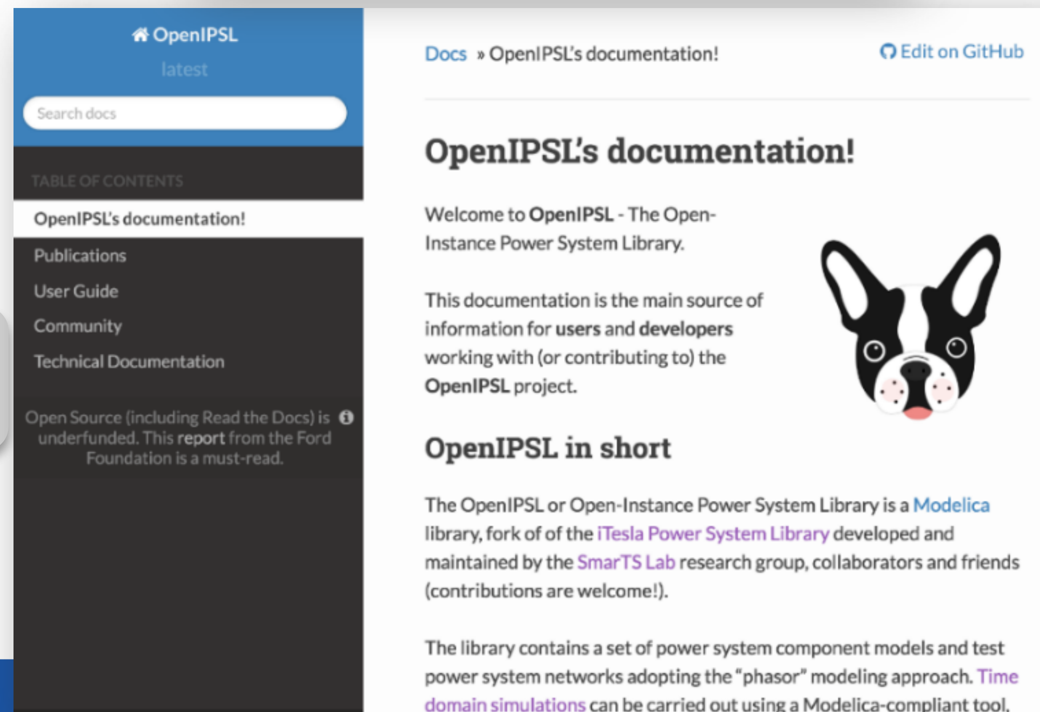
- Documentation of the code changes

→ Explicit messages in ***commits*** and ***pull-requests***

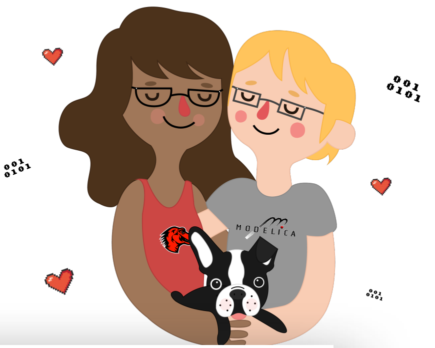
- Documentation of the project
  - Presentation
  - User guide
  - Dev. guidelines & How to contribute

→ The documentation is written in ***reStructuredText*** (reST) hosted on http://openipsl.readthedocs.io/

*Note:* Model documentation is not included, users are referred to the proprietary documentations.

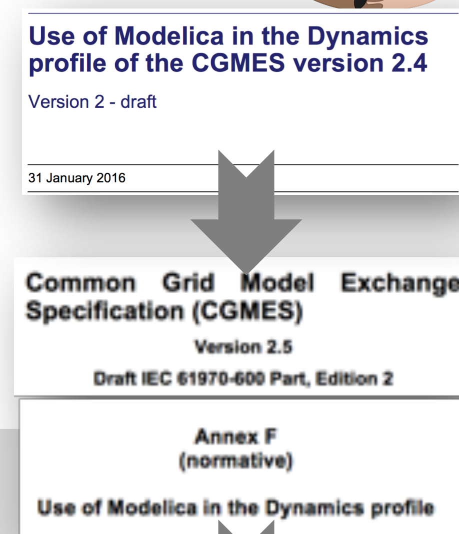



# The *OpenIPSL* Project
## Latest Developments/Contributions




Some of the latest development in the library:

- **100% Compatibility with OM (100% Check, 100% Simulation for components) through efforts in Continuous Integration adoption**
- Change in the models to include inheritance (code factorizing)
- Fixing and validating network models (thanks to CI)
- Component for interfacing OpenIPSL with 3 phase models (aka MonoTri)
  - For distribution grid (unbalanced) simulations
  - Starting point for mixed transmission and distribution network simulations



**Use of Modelica in the Dynamics profile of the CGMES version 2.4**

Version 2 - draft

31 January 2016

**Common Grid Model Exchange Specification (CGMES)**

**Version 2.5**

**Draft IEC 61970-600 Part, Edition 2**

**Annex F (normative)**

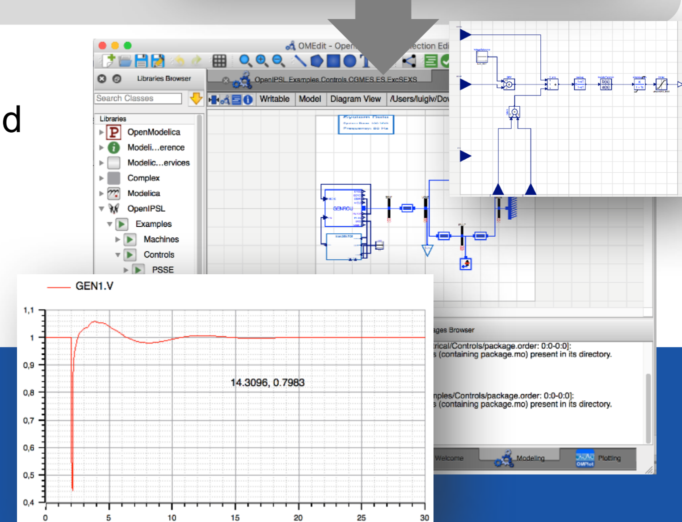
**Use of Modelica in the Dynamics profile**

### ENTSO-E IOP:

- Proof of concept and test model
- Excitation system and small network model

### OpenCPS Models

- Small power network models for analysis of continuous and hybrid systems (sampling and discretized AVR model)
- Process noise (gen./load) **pdf-based** load models added
- Frequency estimation model
- Sequential automated re-synchronization and control model for islanded network



New research requirements and the experiences from previous effort indicated ***a clear need for a different development approach*** **- one** that should address a complex development and maintenance workflow!

How to master a complex development workflow?

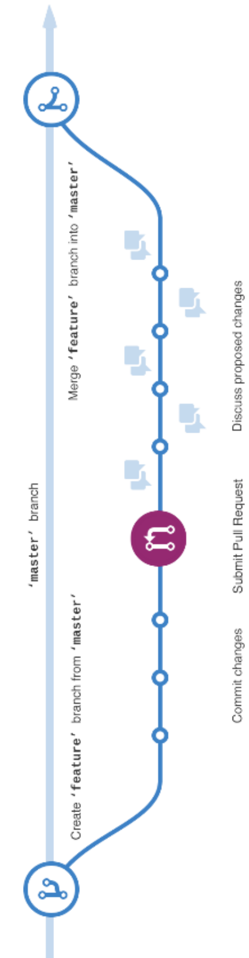
# Continuous Integration

# A Collaborative Workflow

We adopted the ***pull-request*** workflow (or GitHub workflow):

- Participants ***fork*** the repository and work in their repository
- Changes are submitted to the main repository as ***pull-requests***
- The pull-requests are ***reviewed*** by "admin" members of the repository
    - upon ***validation*** the changes are merged in the code of the repository

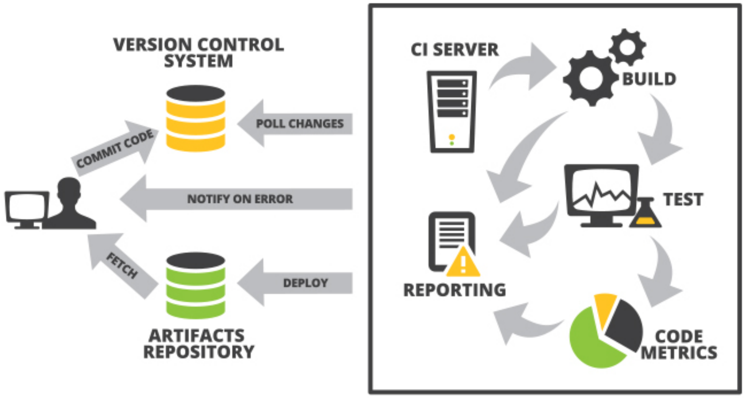
- Mistakes can be made by members of our team, ***we are still learning!***
- The Git workflow adopted allows to minimize the impact of these errors.
- Increased library quality!



# Toward Continuous Integration

- The ***previous workflow*** was used by only ***few people*** and resulted in ***no control*** over the code quality, <u>*even though DVCS was being used.*</u>

- The ***newly adopted*** workflow turned suitable for the development ***team***, but generated a strong ***burden*** for the ***code review***




This sparked the idea of implementing a ***Continuous Integration workflow:***

→ Focus on "***lighter***", ***more frequent*** pull-requests, containing ***less code*** change, all related to a ***single feature*** to facilitate the code validation

→ Implement a CI service to ***automate*** recurring code ***validation tests***, to liberate "admin" resources.

# Continuous Integration (CI) Service

A CI service was implemented and integrated to the repository. The Modelica support was achieved with the following architecture:

- ***Travis*** as CI service provider
- ***Docker*** as the “virtualization” architecture
- ***DockerHub*** to host a Do

Th

New changes are submitted as a new pull request to the master branch

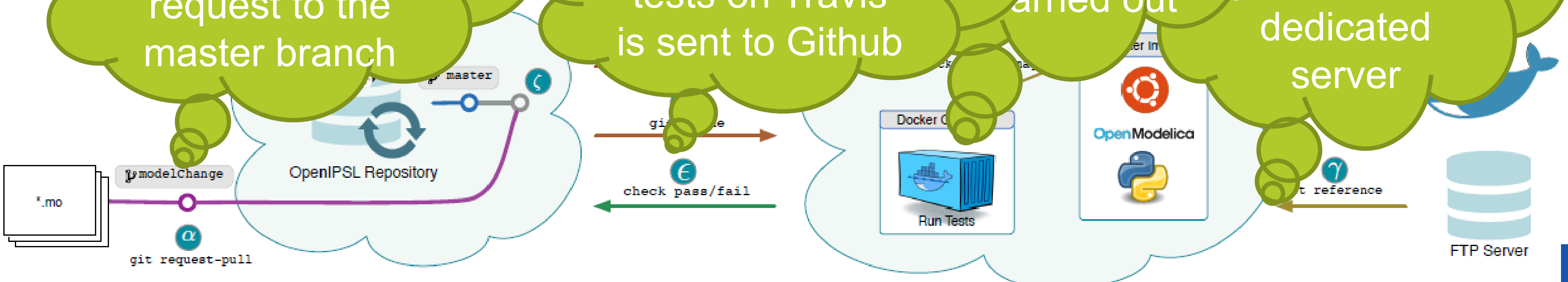
The latest ver
the library c

The pass / fail flag from the tests on Travis is sent to Github

The Docker is instantiated to create a *replicable*
ironment
the tests
arried out

tailored

The
erence
aces are
pulled from a dedicated server



Go to the OpenIPSL Github repo: https://github.com/SmarTS-Lab/OpenIPSL, see runTest.py

| | | |
|---|---|---|
| Application Exam… | Increment the version number for v1.0.0 | 3 months ago |
| CI | C… | |
| OpenIPSL | Merged branch master into master | 2 months ago |
| Support | Update addCopyright with all App E… | |
| docs | (doc) Update some links | |
| .gitattributes | Add a git attributes file that allows i… | |
| .gitignore | Merge branch 'docUpdate' into rele… | |
| .travis.yml | no message | |
| LICENSE | Initial Commit for launching OpenIP… | |
| LICENSE.txt | Resets the EOL of all files and remo… | |
| README.md | (dod) Fix link to the Get Started doc… | |

README.md

build passing

Click to see the IO from Travis

# OpenIPSL: Open-Instance Power System Library:

The OpenIPSL or Open-Instance Power System Library is a fork of of the iTesla Power System Library, currently developed and maintained by the SmarTS Lab research group, collaborators and friends (contributions are welcome!).

Travis CI Blog Status Help

## SmarTS-Lab / OpenIPSL

build passing

Current Branches Build History Pull Requests

✓ Pull Request #86 Update tutorial package

#146 passed

Fix presentation slides

Elapsed time 5 min 2

7 days ago

Commit 1f8d1ff

#86: Update tutorial package

Branch master

Maxime Baudette authored and committed

Job log View config

```
Worker information
Build system information

$ export DEBIAN_FRONTEND=noninteractive
$ git clone --depth=50 https://github.com/SmarTS-Lab/OpenIPSL.git SmarTS-Lab/OpenIPSL
$ sudo service docker start
$ bash -c 'echo $BASH_VERSION'
4.3.11(1)-release
$ docker pull smartslab/ci_openipsl
$ docker run -i -t -v $(pwd):/OpenIPSL smartslab/ci_openipsl sh /OpenIPSL/CI/changeUser
2017-01-30 10:57:35,609 - OMCSession - INFO - OMC Server is up and running at
file:////tmp/openmodelica.smartslab.objid.ccfdcd8d55c94521a04f0d9a6cf737a5
/OpenIPSL/package.mo is successfully loaded.
```

```
==== Check Summary for OpenIPSL ====
Number of models that passed the check is: 268
Number of models that failed the check is: 0
/Application Examples/TwoAreas/package.mo is successfully loaded.
==== Check Summary for TwoAreas ====
Number of models that passed the check is: 16
Number of models that failed the check is: 0
/Application Examples/SevenBus/package.mo is successfully loaded.
==== Check Summary for SevenBus ====
Number of models that passed the check is: 4
Number of models that failed the check is: 0
/Application Examples/N44/package.mo is successfully loaded.
==== Check Summary for N44 ====
Number of models that passed the check is: 38
Number of models that failed the check is: 0
/Application Examples/KundurSMIB/package.mo is successfully loaded.
==== Check Summary for KundurSMIB ====
Number of models that passed the check is: 7
Number of models that failed the check is: 0
/Application Examples/IEEE9/package.mo is successfully loaded.
==== Check Summary for IEEE9 ====
Number of models that passed the check is: 5
Number of models that failed the check is: 0
/Application Examples/IEEE14/package.mo is successfully loaded.
==== Check Summary for IEEE14 ====
Number of models that passed the check is: 6
Number of models that failed the check is: 0
/Application Examples/AKD/package.mo is successfully loaded.
==== Check Summary for AKD ====
Number of models that passed the check is: 3
Number of models that failed the check is: 0


The command "docker run -i -t -v $(pwd):/OpenIPSL smartslab/ci_openipsl sh /OpenIPSL/CI/changeUser.sh" exited with 0.

Done. Your build exited with 0.
```

# Extension of the CI Service

The ***first implementation*** eliminated parts of the ‘*rebarbative’* tasks by automating the ***code checks***:

- Avoid error propagation in the library, models “out-of-sync”
- Implementation entirely based on ***OpenModelica***
  → ***100% OM Compatibility*** achieved !

From this successful implementation, an extension was investigated to ***include model validation*** into the CI service:

- Model validation tests were carried out “offline” during the model development stages
  → ***We did it before***!
- Automated model validation (aka regression testing), ensures code changes won’t affect existing models
  → Library ***integrity guaranteed***

# Model Validation Workflow (SW-to-SW) (1/2)

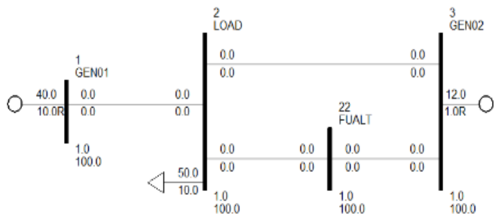
In the original implementation of the models of the OpenIPSL, a software-to-software validation workflow was designed and carried out "offline":

- Models are implemented from several ***reference programs***
  - ***PSAT***, domain specific tool in MATLAB/Simulink by F. Milano
  - ***PSS/E***, domain specific tool from Siemens PTI
- Modelica models were validated using ***small scale*** power network
- The traces from the Modelica models were qualitatively and quantitatively assessed: compared to the ***reference traces***

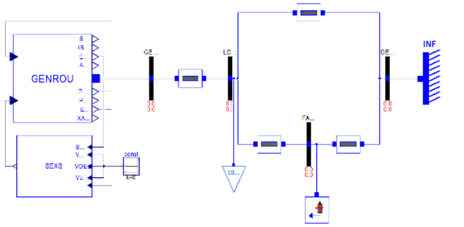
→ Gives ***confidence*** to users having a long experience with these reference software …

# Model Validation Workflow (SW-to-SW) (2/2)

**Reference SW Tool**




**Modelica Model**




Power Flow Calculations

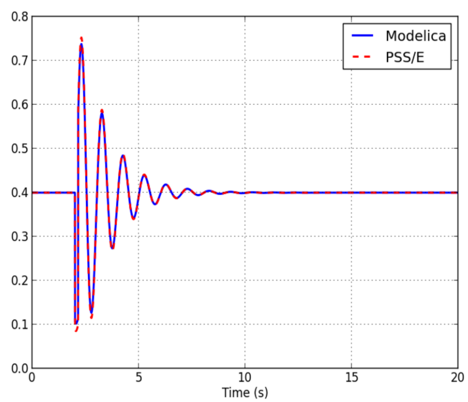
Time-domain simulation

Time-domain simulation

**Graphical and Quantitative Assessment**

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - y_i)^2}$$

Signal P




| Model | Validation Result |
|---|---|
| EXAC1 | Fail |
| EXAC2 | Fail |
| EXST1 | Pass |

| Signal | RMSE | Plot |
|---|---|---|
| P | 2.8389e-3 | + |

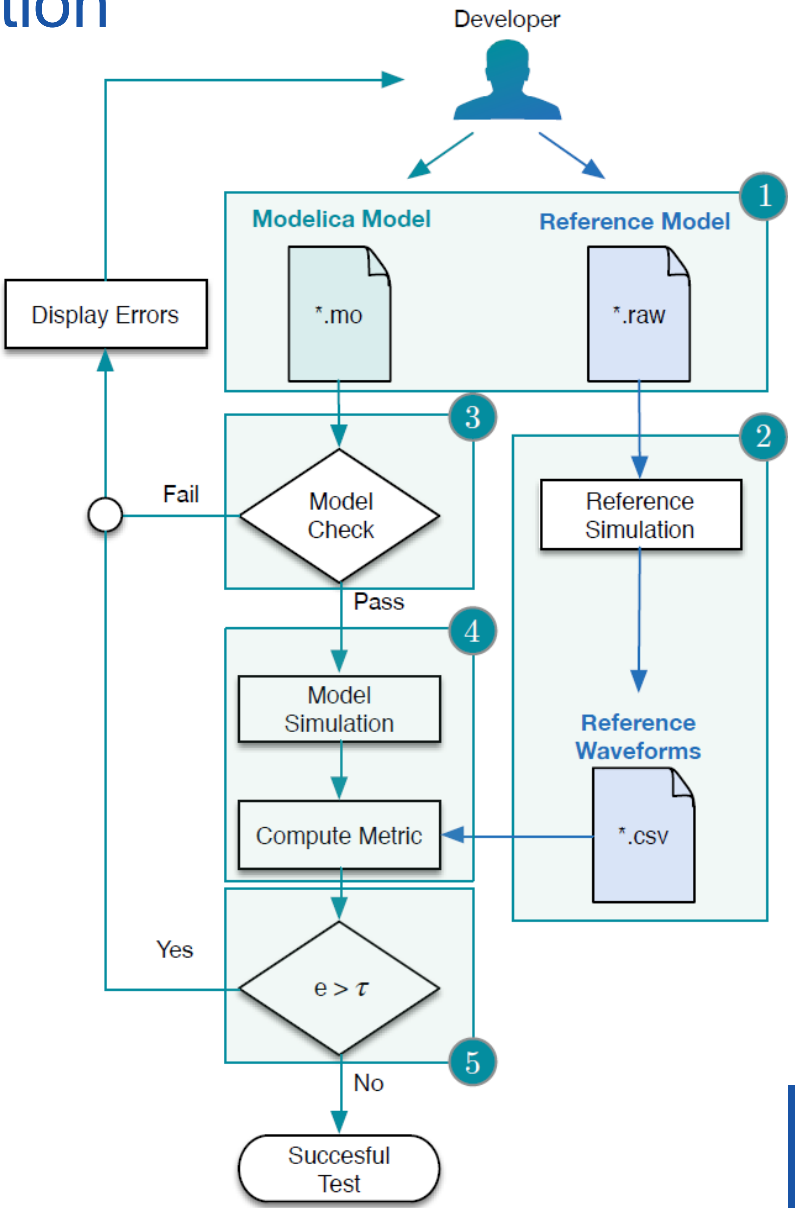
# Continuous Integration (CI)

## Full workflow implementation

Workflow Summary:

- A two-stage process
  - Modelica ***syntax*** check
  - Model ***validation*** check
- Fully automated through online CI services

→ Diagnostic help to the developers to ***locate the error***



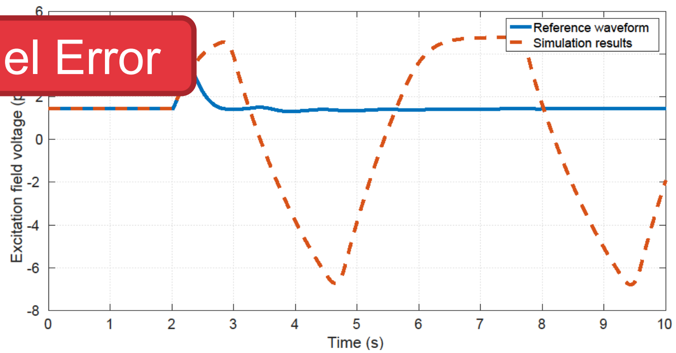
# Continuous Integration (CI)
## GitHub Integration

Syntax Error

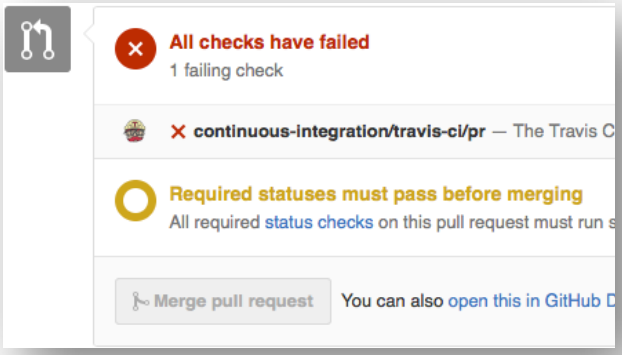
```
penIPSL/Examples/Controls/PSSE/ES/IEEEX1.mo
1:80:readonly] Error: Variable iEEEX1_1: In
modifier (KA = 75), class or component KA not found
in <OpenIPSL.Electrical.Controls.PSSE.ES.
IEEEX1$iEEEX1_1>.
Error: Error occurred while flattening model OpenIPSL.
Examples.Controls.PSSE.ES.IEEEX1
```

OR

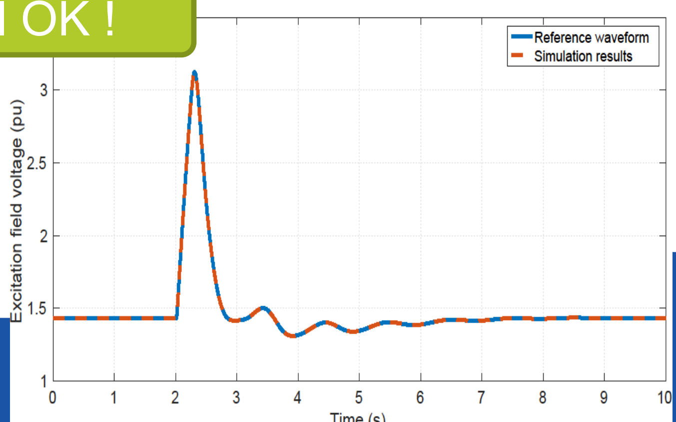
Model Error



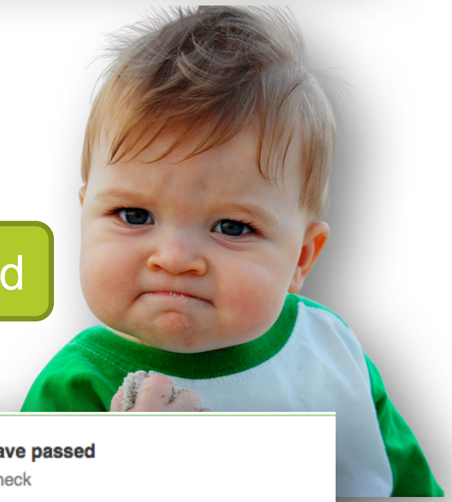

Merging Blocked

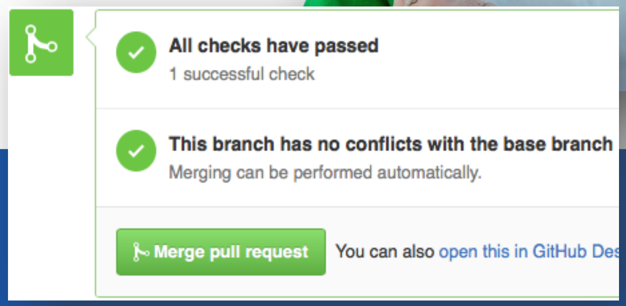



All OK !




Merging Allowed





# Questions?

***Main Take Away(s)***

The implementation of Continuous Integration services allows to:

- Systematically check the code syntax
- Systematically check the integrity of the library (through SW-to-SW validation)

→ Easier collaboration with more developers

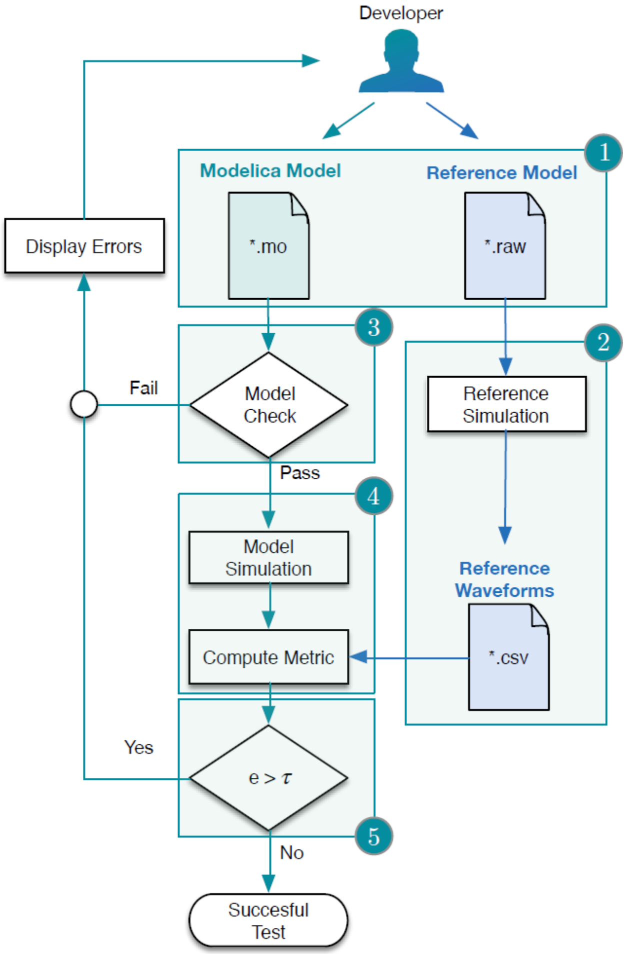
→ Easier to diagnostic potential errors

→ Better code quality

Other existing Modelica libraries could adopt CI:

→ Better compatibility with OM and

→ Modelica language version(s).

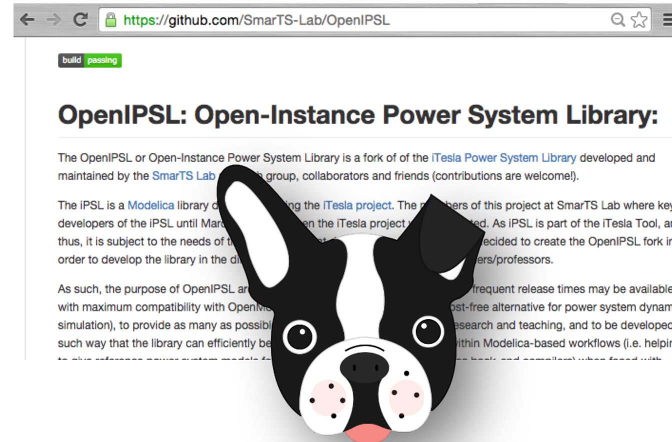


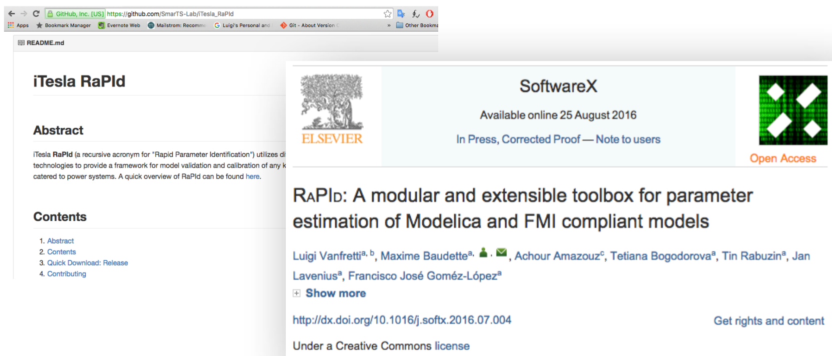

The **OpenIPSL** library can be found online: https://github.com/SmarTS-Lab/OpenIPSL

**Let's now learn to use *OpenIPSL*!**

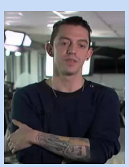
The **OpenIPSL** can be found online
- https://github.com/SmarTS-Lab/OpenIPSL

Our work on **OpenIPSL** has been published in the SoftwareX Journal:
- http://dx.doi.org/10.1016/j.softx.2016.05.001



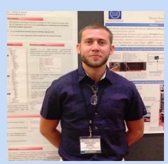




**RaPId**, a **system identification** software that uses OpenIPSL can be found at:
- https://github.com/SmarTS-Lab/iTesla_RaPId
- http://dx.doi.org/10.1016/j.softx.2016.07.004


Luigi Vanfretti

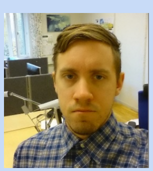

Achour Amazouz


Mohammed Ahsan Adib Murad


Francisco José Gómez

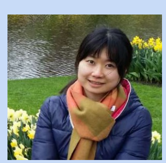

Giuseppe Laera


Tin Rabuzin

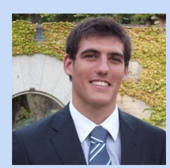

Jan Lavenius


Le Qi


Maxime Baudette


Mengjia Zhang


Tetiana Bogodorova


Joan Russiñol Mussons

*Thanks* to all current and former students and developers at

SmarTS Lab
Smart Transmission Systems Laboratory