Development and Continuous Integration of the *OpenIPSL*

Modelica Library for Power Systems Simulation

Maxime Baudette, Tin Rabuzin and ***Luigi Vanfretti***

Assoc. Prof. Luigi Vanfretti - luigiv@kth.se https://www.kth.se/profile/luigiv/

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Outline

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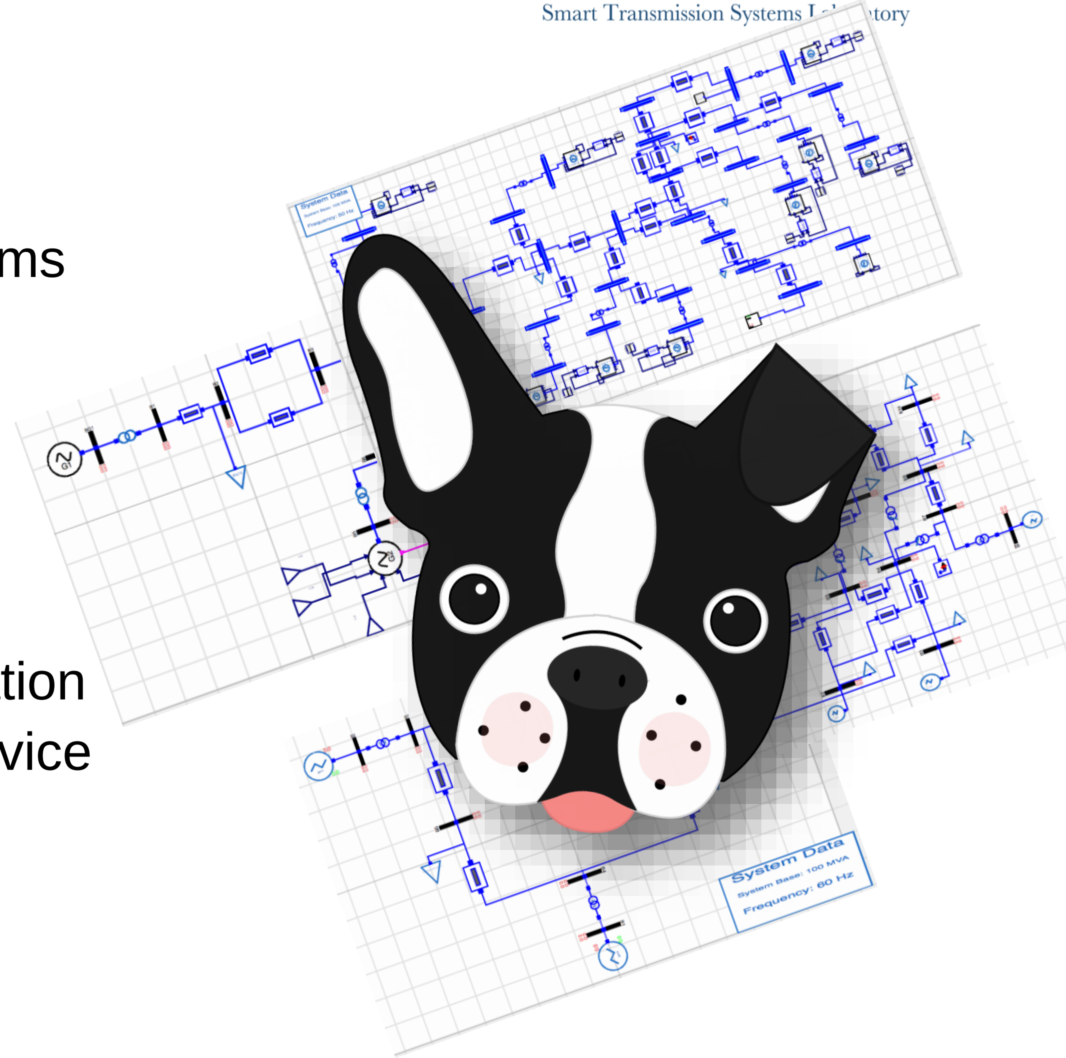
- **Continuous Integration**
  - A Collaborative Workflow
  - Toward Continuous Integration
  - Continuous Integration Service
  - Extensions
  - Model Validation
  - GitHub Integration



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 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 OM.

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 or OpenIPSL)

Social Aspects (Vanfretti et al, Modelica 2014):

- Resistance to change: irrational and dysfunctional reaction of users
  - Users of conventional power system tools are skeptical about any other tools different to the one they use (or develop), and have concerns about new technologies (lack of knowledge)
- Change agents contribute (+/-) to address resistance through actions and interactions:
  - Did not impose the use of a software tool, instead:
  - Propose a common math. “description”: use of Modelica for unambiguous model exchange.
- Decrease avoidance forces:
  - SW-to-SW validation give quantitatively an similar answer than domain specific tools.

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 ***i**Tesla* 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*

The *OpenIPSL* Library

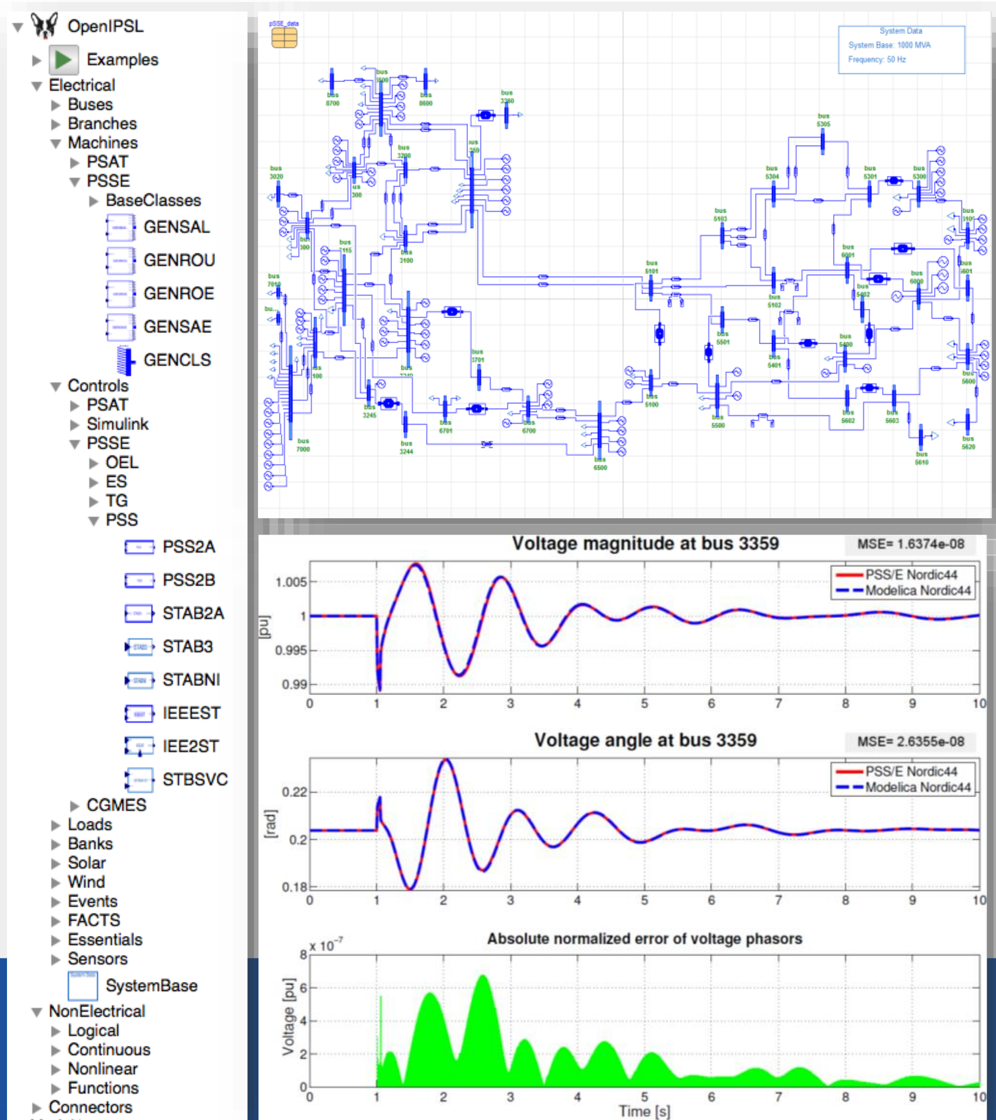
OpenIPSL

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



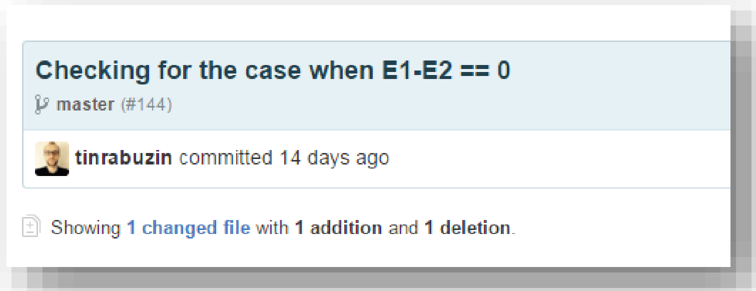
The *OpenIPSL* Project Documentation

OpenIPSL

The intention is to have comprehensive documentation in the repositories:

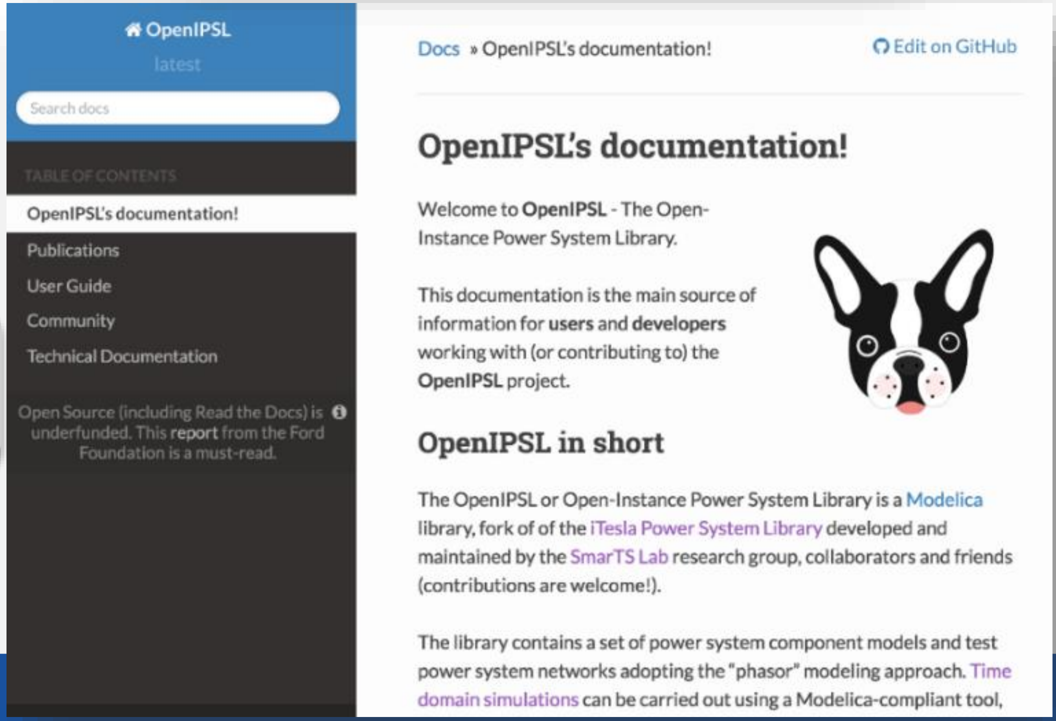
- Documentation of the code changes

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



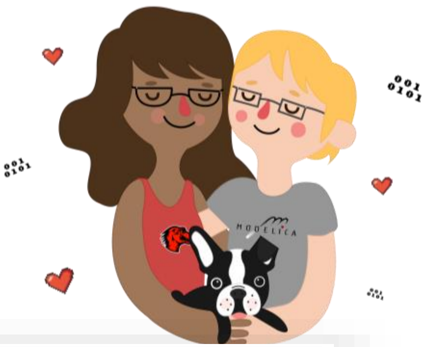
- Documentation of the project
  - Presentation
  - User guide
  - Dev. guidelines & How to contribute

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

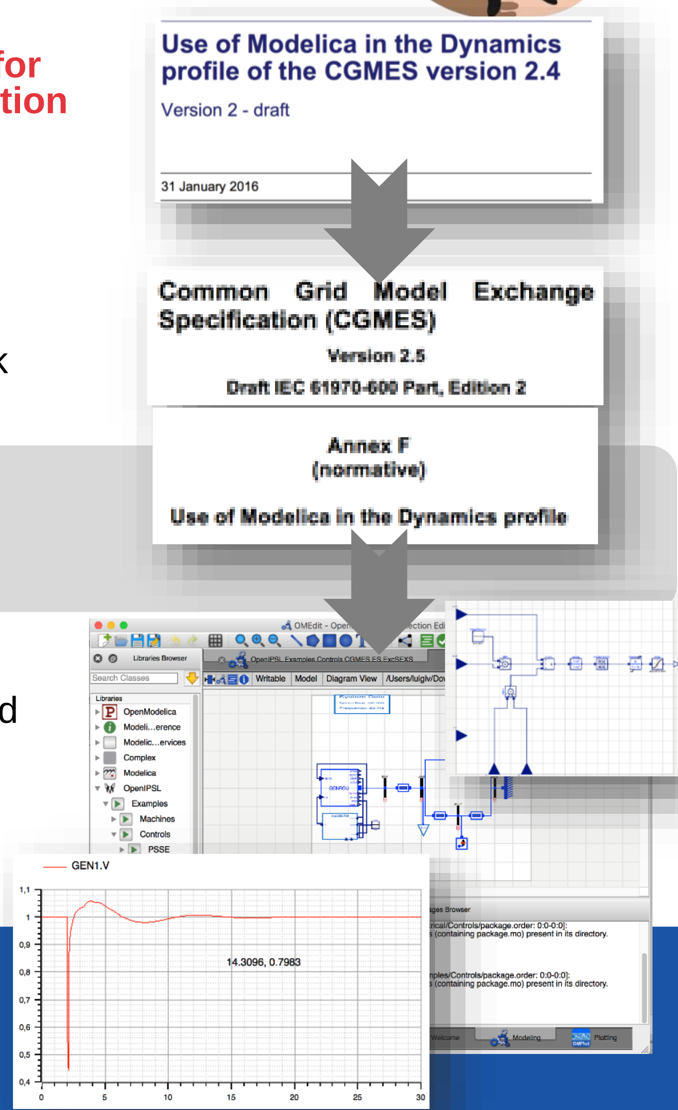


Note: Model documentation is not included, users are referred to the proprietary documentations.

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



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)
- Use case examples being developed will be added soon.

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!

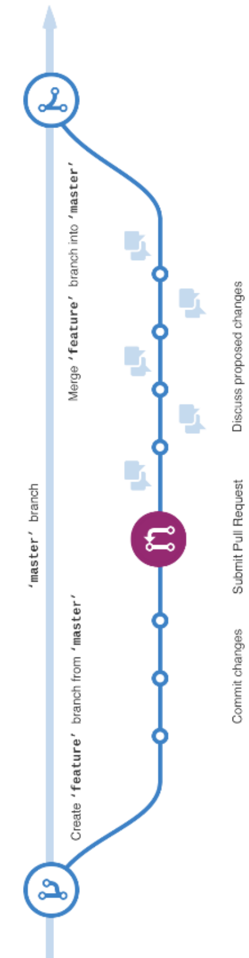
How to master a complex development workflow?

Continuous Integration

A Collaborative Workflow

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

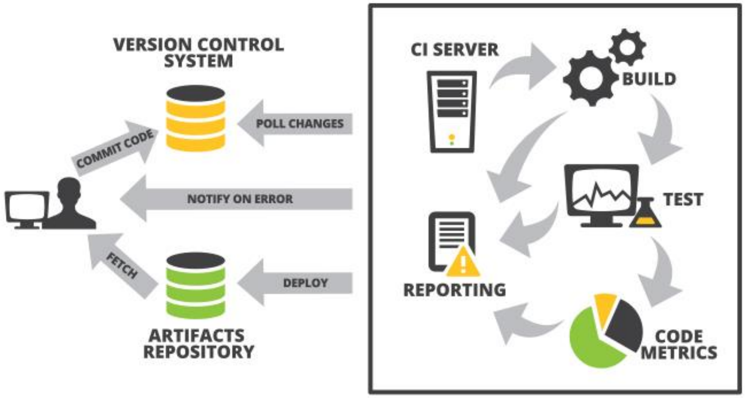
- Participants ***fork*** the repository and work in their repository
- Changes are submitted to the main repository as ***pull-requests***
- The pull-requests are ***reviewed*** by “admin” members of the repository
    - upon ***validation*** the changes are merged in the code of the repository



- 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, *even though DVCS was being used.*
- 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

The latest vers
the library c

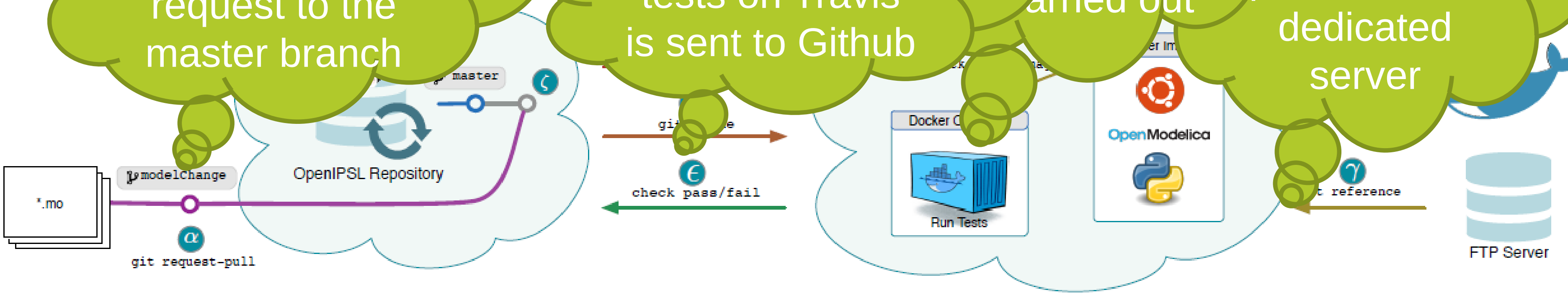
The Docker is instantiated to create a *replicable* ironment the tests arried out

tailored

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

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

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	
.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

Fix presentation slides

Commit 1f8d1ff

#86: Update tutorial package

Branch master

Maxime Baudette authored and committed

#146 passed

Elapsed time 5 min 2

7 days ago

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)

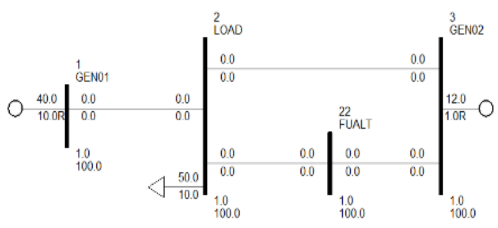
In the original implementation of the models of the OpenIPSL, a software-to-software validation workflow was designed and carried out "offline":

- 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 …

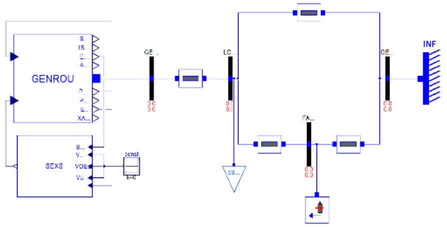
Model Validation Workflow (SW-to-SW) (2/2)

Reference SW Tool



Power Flow Calculations

Modelica Model



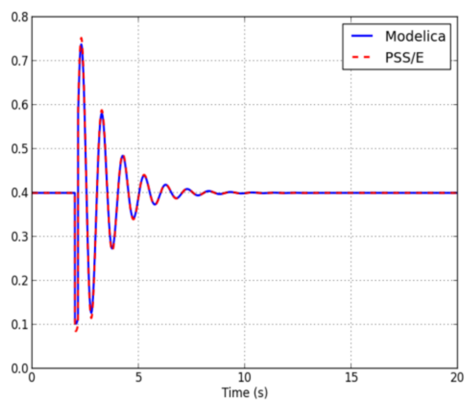
Time-domain simulation

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

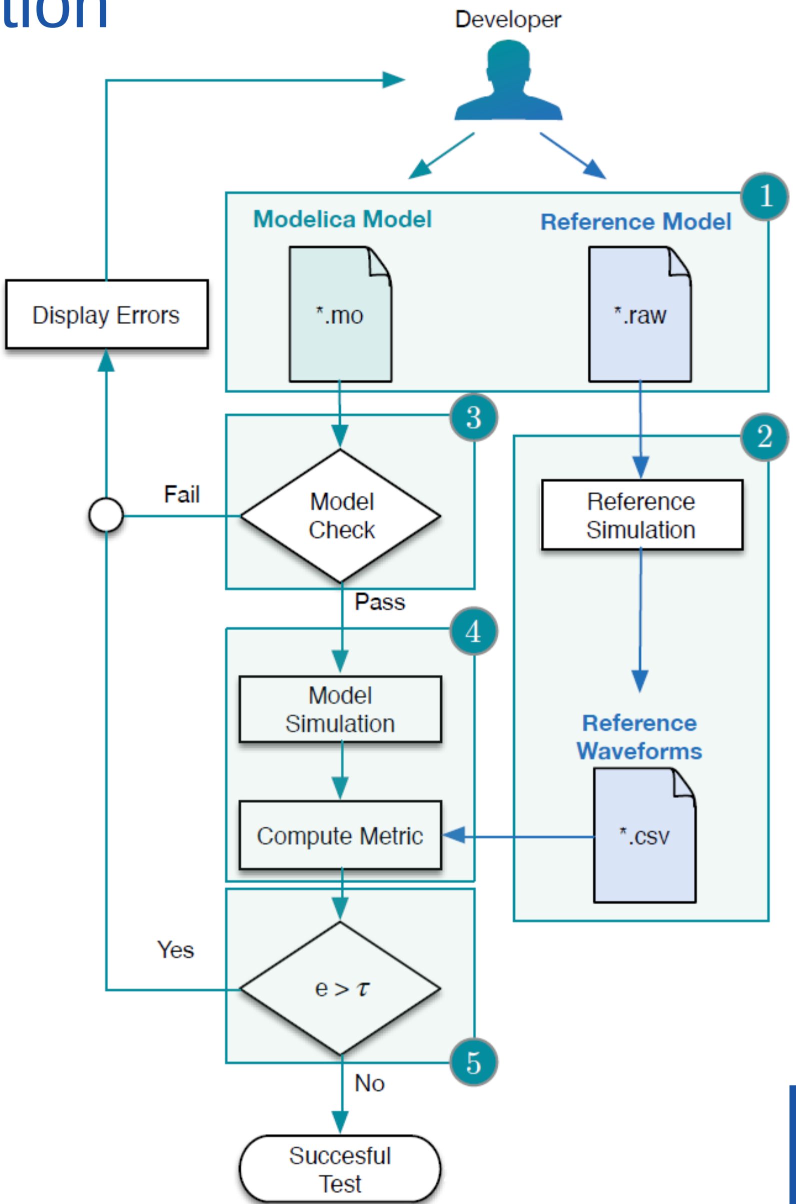
Signal	RMSE	Plot
P	2.8389e-3	+

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)

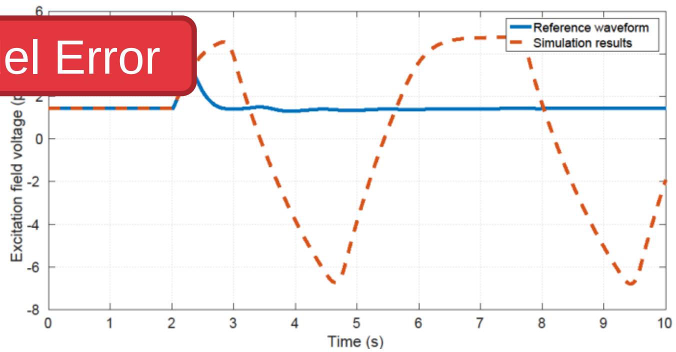
GitHub Integration

Syntax Error

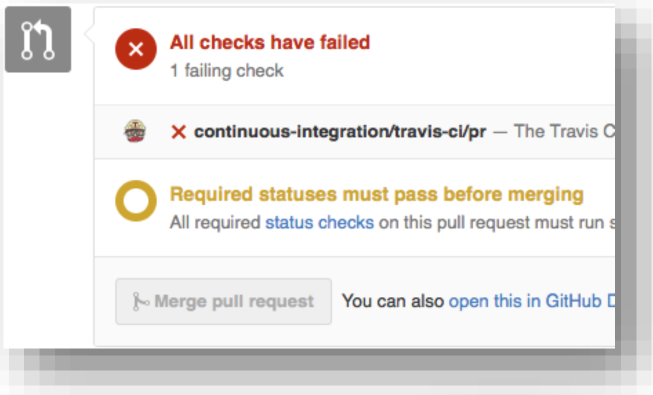
```
penIPSL/Examples/Controls/PSSE/ES/IEEEX1.mo
:80:readonly] Error: Variable iEEEX1_1: In
modifier (KA = 75), class or component KA not found
    in <OpenIPSL.Electrical.Controls.PSSE.ES.
    IEEEX1$iEEEX1_1>.
Error: Error occurred while flattening model OpenIPSL.
    Examples.Controls.PSSE.ES.IEEEX1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

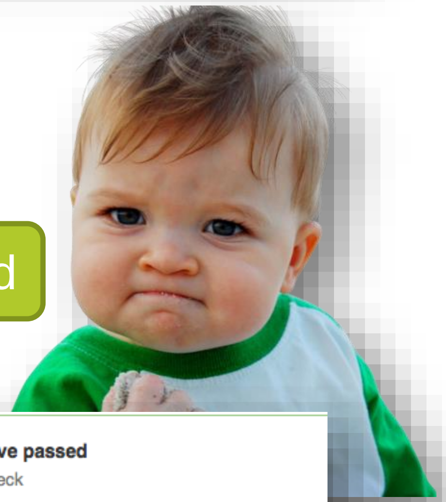
OR

Model Error

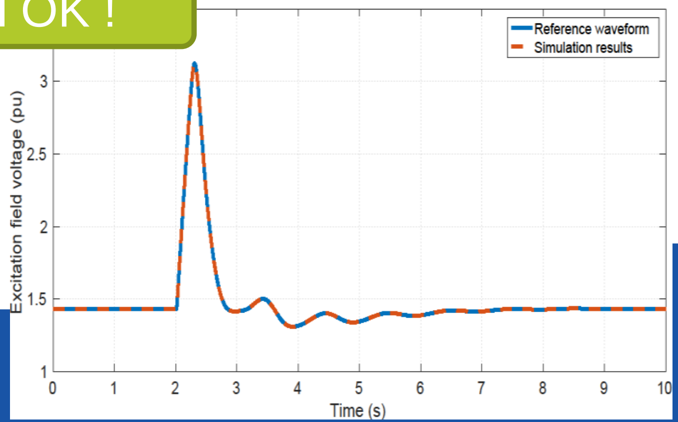


Merging Blocked

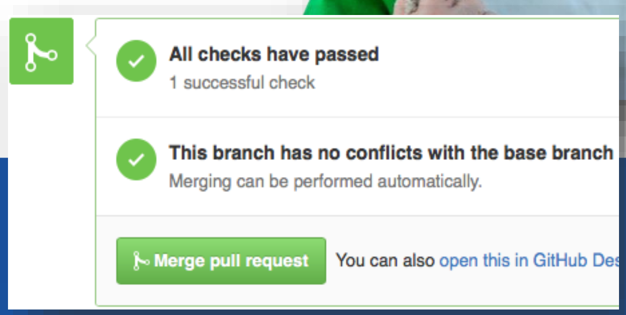




All OK !



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

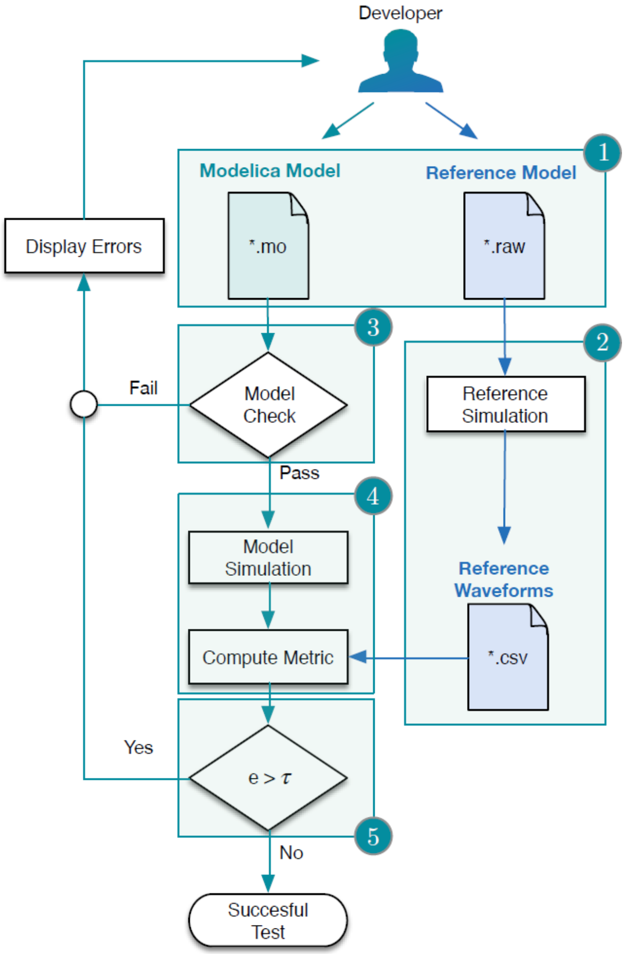
→ Easier to diagnostic potential errors

→ 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

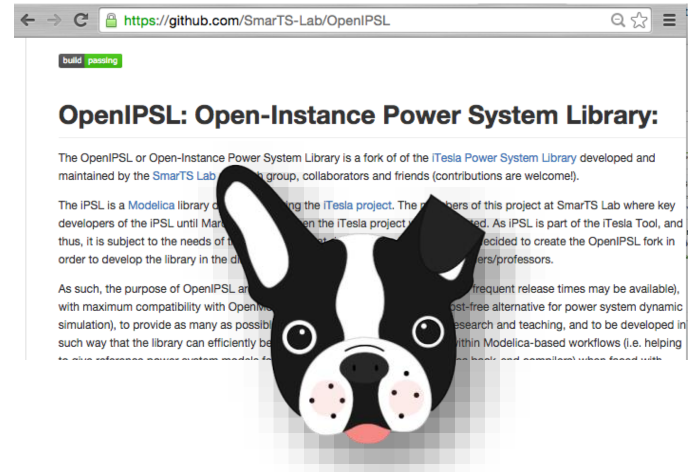
Come to the MODPROD Tutorial 3 to learn to use *OpenIPSL*!

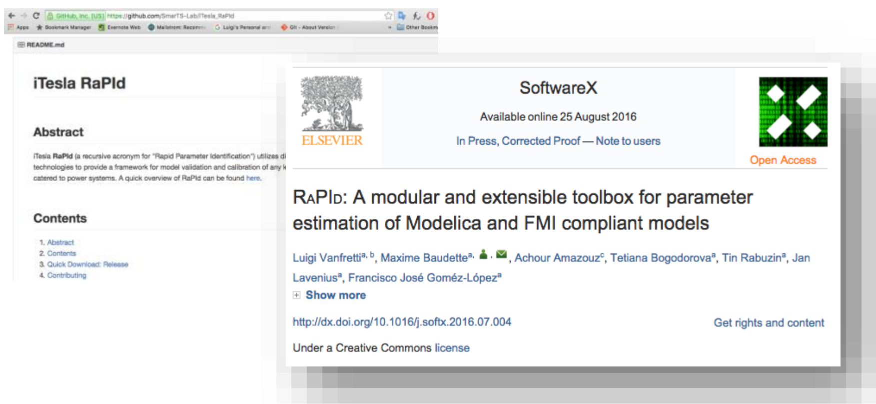
The **OpenIPSL** can be found online

- 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





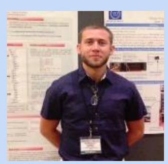
RaPId, a **system identification** software that uses OpenIPSL can be found at:

- 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

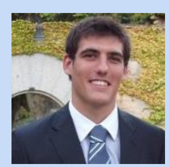

Jan Lavenius


Le Qi


Maxime Baudette


Mengjia Zhang


Tetiana Bogodorova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