Research Interns @Strathclyde (RIAS)

Project Report

Please save the completed report as a pdf file and upload to MyPlace before 12.00 on Thursday 16 September 2021. Please ensure the filename is clear and contains your name and project title.

A. Project details

Name	Samuele Martinelli
Project title	Simulating the future renewable-based power network: High-performance computing for power systems analysis
Department/School	Engineering Department
Supervisor(s)	Dr A. Egea Alvarez, Dr P. Papadopoulos
Funder(s) (e.g. RIAS; EPSRC; Carnegie; MRS)	EPSRC

B. Project report

In no more than 800 words, please give a complete account of: a) the research undertaken; b) methodologies applied and ethics considered; c) key findings; and, d) conclusions and outcomes.

INTRODUCTION

The standard simulation method for electric networks is Root Mean Squared (RMS) simulations, which models the grid lines at one fixed frequency, ignoring systems that work at different frequencies (e.g., power electronics) [1]. ElectroMagnetic Transient (EMT) simulations use time domain differential equations to model the components of the system. Allowing to capture with great accuracy the results of a grid simulation with components that work at different frequencies. However, EMT simulations take much longer time to simulate compared to RMS simulations [2]. This project investigates different methods of simulating grid networks. MATLAB is used to simulate for RMS and EMT methods, investigating compilers ode23tb and ode45. PSCAD supports only EMT simulations, and two versions are used , PSCAD 5 with compiler GFortran 8.1 and educational license and PSCAD 4.6.3 with compiler GFortran 4.6.1 and professional license. Parallel core computing in PSCAD (PNI) is investigated as well. PNI is a technique that allows to split a big system (from one project) to multiple sub-systems (in more, interconnected, projects). Each sub-system is solved in a separated CPU core.

METHODOLOGY

Three different study models were investigated. The first one, one transmission line, is a simple transmission line connecting a generator to a load. It was used to gain familiarity with the software and timing script, while

also collecting data for a small basic system.

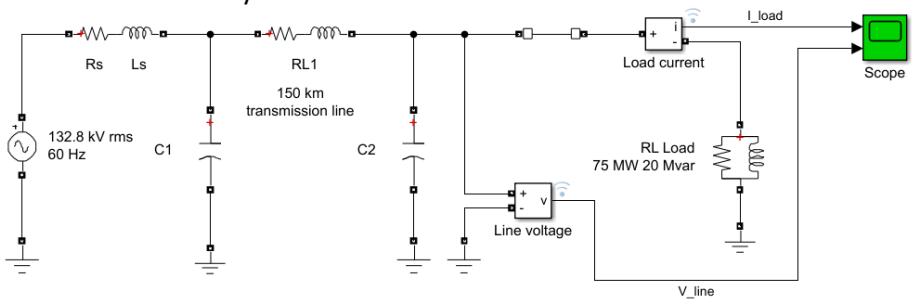

Figure 1: "one transmission line" system in MATLAB/Simulink

The second study model, PV farm grid, was selected to study the effect of a system that includes switches (which usually take long to simulate). The PV farms comprehend a boost converter and a Voltage Source Converter (VSC), both including switches. The PV farm system is connected to the grid and a load via a bus. This model was also used for gaining familiarity with PNI simulations.

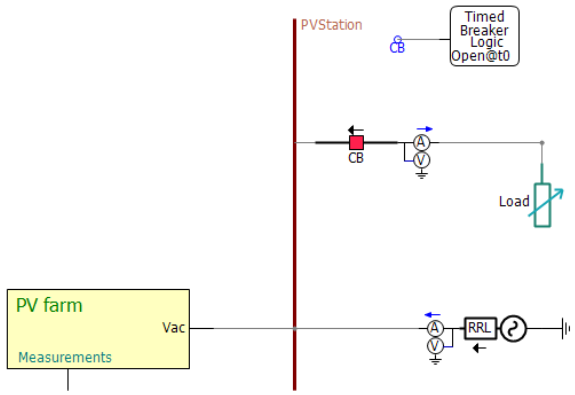

Figure 2: PV farm connected to the grid in PSCAD

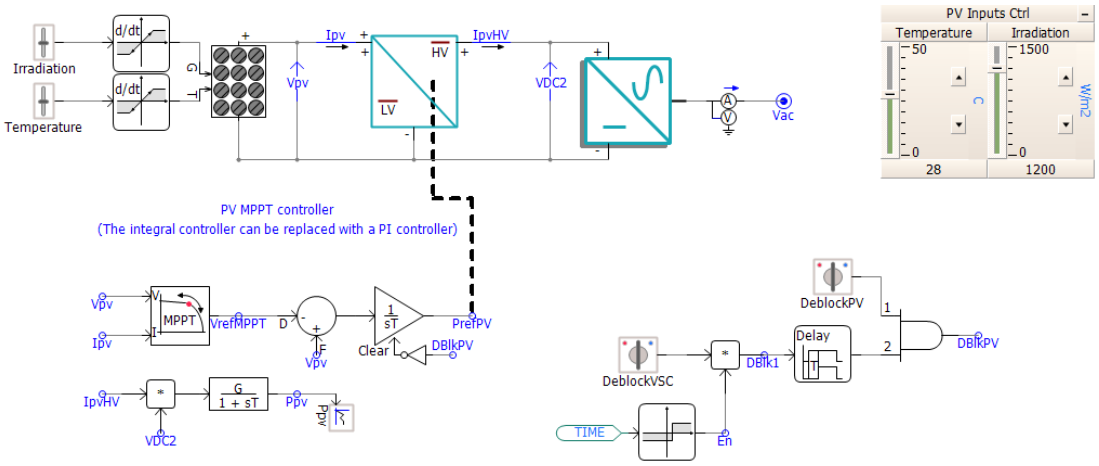

Figure 3: PSCAD's PV farm subsystem

The third, and last, study model, IEEE 39 Bus System with PV farms was used to investigate a more complex system including renewable source generators (two identical PV farms, one connected in bus 32 and the other in bus 38). This project was also used to investigate different PNI scenarios, one in which just one PV farm is solved on a separated core of the computer (2 projects), and another one in which the two PV farms are in solved each in their own project (3 projects).

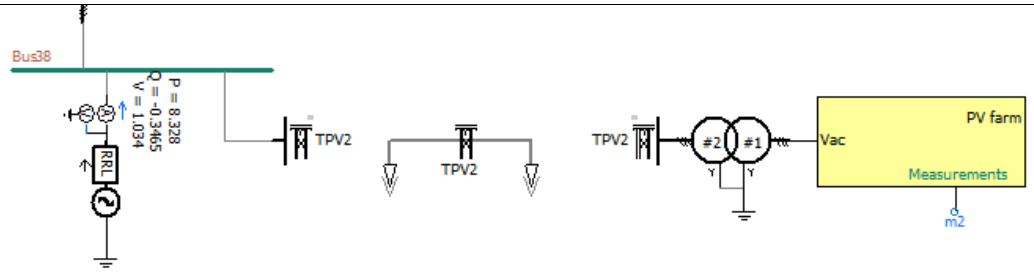

Figure 4: Example of PV farm connected to a bus of the IEEE 39 Bus System

For the same project 10 simulations were run and the simulation time collected. The collected data is then represented in box plot, in order to give a quantitative graphical representation.
The tests were performed on a laptop Asus N552VW with processor Intel Core i7-6700 HQ (4 cores) and a 16 GB RAM.

RESULTS & DISCUSSION

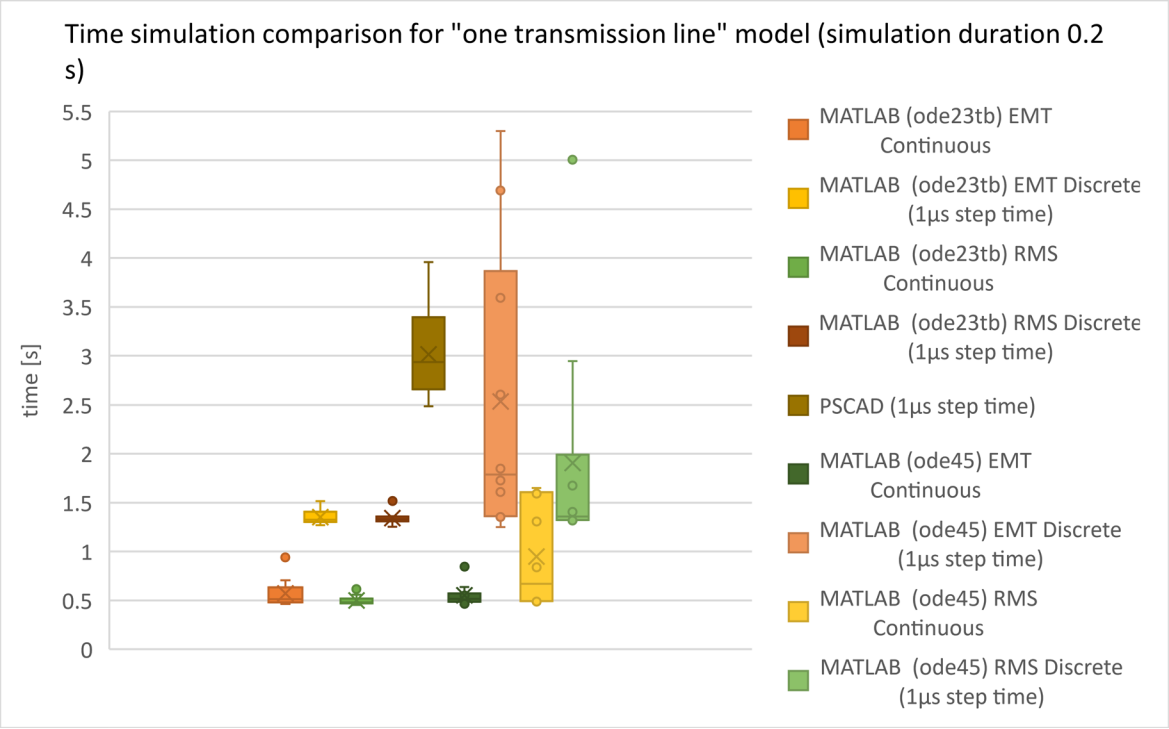

Figure 5: Time simulation comparison for "one transmission line" model

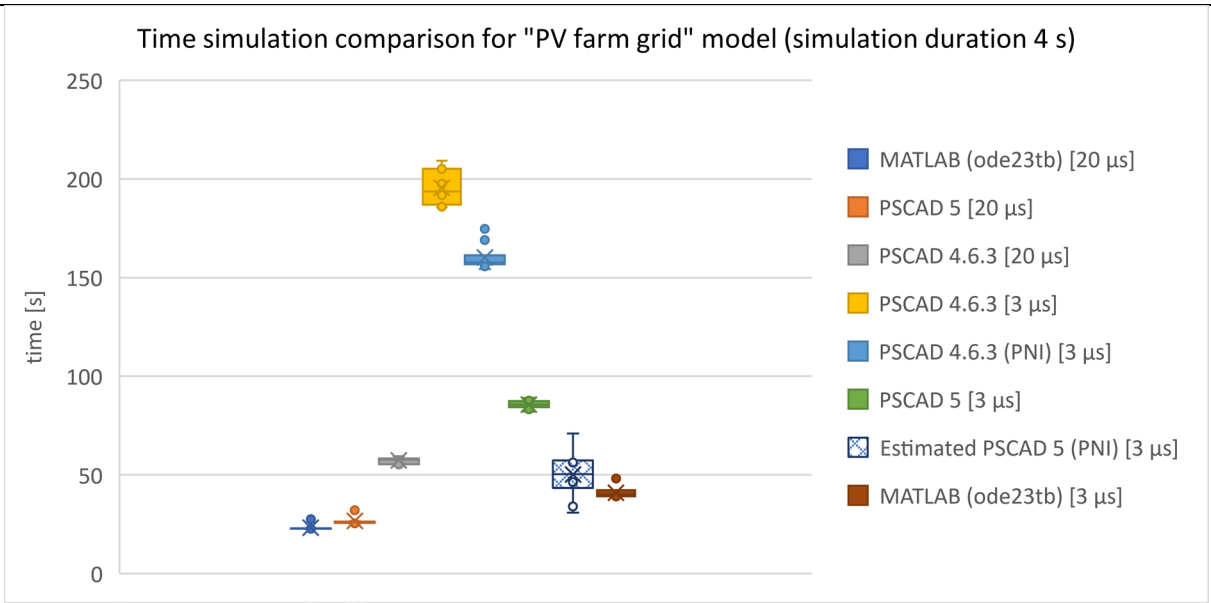

Figure 6: Time simulation comparison for "PV farm grid" model

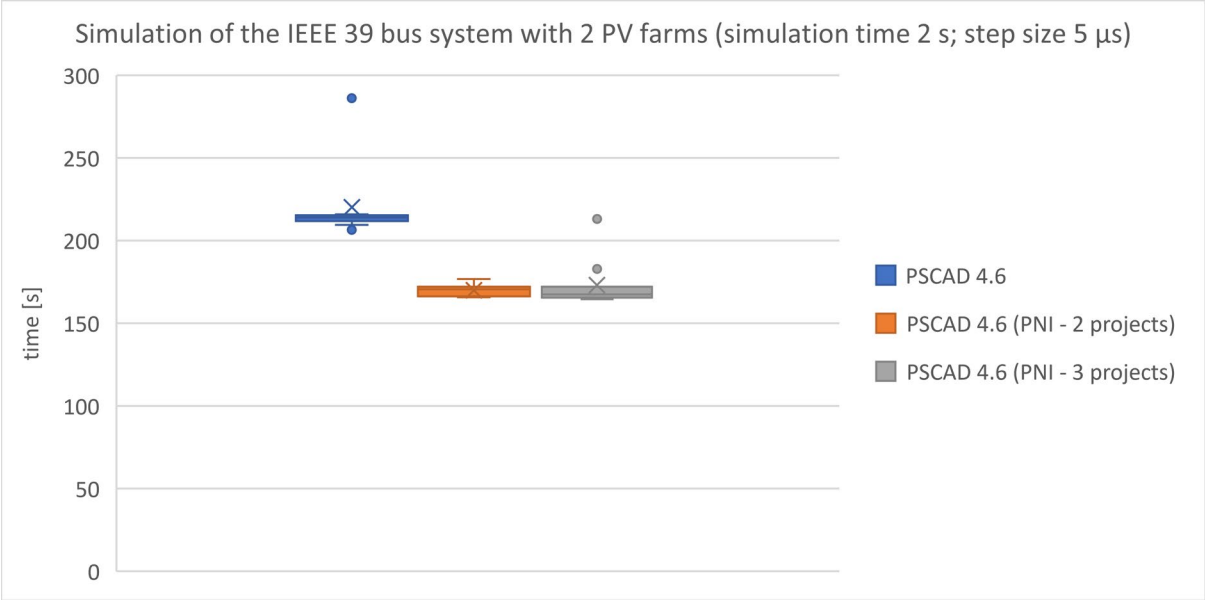

Figure 7: Time simulation comparison for the IEEE 39 bus system with 2 PV farms

The results showed that MATLAB is faster than PSCAD (in which ode23tb is a faster compiler than ode45). Continuous simulations are faster than discrete ones because the step size of simulation is variable.

PSCAD 5 is faster compared to version 4.6.3, this is probably caused by the updated GFortran compiler. However, limitations in the license prevented version 5 from using PNI (an estimate based on the time saved in PSCAD 4.6.3 is shown in Figure 6) and with the IEEE 39 Bus System.

In PSCAD 4.6.3 was found that the use of PNI helped improving the computational power, decreasing the simulation duration time. Nevertheless, in the IEEE 39 bus system no improvement was found in the 3 project tests compared to the 2 projects ones. This might depend on the fact that in the used laptop only 4 cores were available and the OS and other background tasks make use of these cores as well, thence not being available to be fully used by PSCAD.

CONCLUSIONS

The duration of a simulation depends on several factors, even within the same computer. The use of different software and compilers can highly affect the time needed to run a simulation, as well as ambient factors. It was shown how parallel computing help reducing this time, however further tests are required in this field with more appropriate computers.

Intel Fortran is supposed to be generally faster than GFortran, further investigations with this compiler in PSCAD

are needed.
Cluster Launch System (CLS) is a PSCAD utility that allows to use PNI over multiple computers in the same Local Area Network (LAN). Studies investigating this tool are needed.

REFERENCES

[1] L. Steinhäuser, M. Coumont, S. Weck, and J. Hanson, 'Comparison of RMS and EMT Models of Converter-Interfaced Distributed Generation Units Regarding Analysis of Short-Term Voltage Stability', *NEIS Conf.*, p. 6, 2019.
[2] N. Watson and J. Arrillaga, *Power Systems Electromagnetic Transients Simulation*, 1st ed. London: IET, 2003.

C. Skills, knowledge and experience

In no more than 200 words, please explain the skills, knowledge and experience you feel you have developed or acquired as a result of undertaking this research project. You may wish to describe how this experience will help you in your future study and/or career plans.

I had the chance to learn several things in this research experience, I had the chance to learn different things about how the electricity grid network is approached in simulation, and what are the industry standards in this matter. I also have the chance to learn new software that could be useful in my future. I also improved different skills that can help me in the future in a workplace, either in academic research or industry.

Last year I did a research internship and this year another one so I have two different experiences that I can take as example for what's next. One thing that I saw in these two internships is the importance in finding a research project that you really enjoy doing, otherwise it is a hassle working on it.
For my future, I'm still open for many options, in my 4th year of high school I didn't want to do University, and one year later I was taking a flight to Glasgow, everything can change, but for now I'm very prone to continue my path towards the research and a PhD!