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On the portability of EMT models in different power system simulation software tools

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Abstract. This paper presents the investigation carried out on the portability and compatibility of a model in different simulation software. The offer of simulation software for power system simulation is wide, with each program having its own modelling interface and its own methods of model development. The lack of a widespread standard for portability between applications implies that the same organisation needs to carry out studies on different applications, requiring the development of a model of the same element or system for each application. This study presents an example of the integration of an inverter model in DigSilent, PSCAD and Simulink by means of the Multilink tool. Throughout the article, the differences found when performing the integration and the same simulation scenario in these three simulation tools are listed. It concludes with a comparison of the results obtained from an electromagnetic transients (EMT) simulation in the three simulation software. The results show a greater similarity between PSCAD and Simulink, with respect to the results obtained in DigSilent.

Key words. DIGSILENT, MATLAB, MULTILINK, PSCAD, SIMULINK.

1. Introduction

Nowadays, the verification of compliance with the grid code for the grid connection of an electrical project cannot be carried out without the prior execution of simulations in one of the many simulation tools available on the market [1]. As there is no unanimity in the use of any of them, or standards for the integration of models in these software, the manufacturer of the electrical plant is obliged to create a model of his product for each software.

This problem has been in the spotlight of the electricity and simulation industry for years. First of all, the different possibilities for the portability of a model from one simulation software to another have to be discussed. In the study [2], three options are presented: “External call procedures between applications”, “DLL-based models” and the use of “Models based on standardised programming languages”.

The first of these options deals with the possibility of communicating and exchanging information between different applications, being able to reach co-simulation. This method is often used to link electrical simulations with other specialised software in other areas, such as thermomechanical processes [3], in which the effect of faults in the network is studied. Also, by this method, communication has been achieved between PSCAD and two simulators for EMT simulations [4], as well as the connection between electromechanical simulations (RMS) with EMT simulations, as is the case of Siemens, which offers the possibility of communicating PSS/E and PSCAD [5]. With Matlab, there are also numerous studies on its use for co-simulation with other software [6]-[9]. This method involves the difficulty of incompatibilities between the tools and their resolution method or integration technique.

The other two methods mentioned in [2] would aim at the possibility of simulating the same model in various software. These methods are via a Dynamic Link Library (DLL), which is a piece of code that can be created using a compiler or a programming language, and via CIM [10] (Common Information Model). The CIM is an open standard for representing the components of electrical power systems and facilitating data exchange. The study [11] shows how CIM is used to describe the power system network model and how it facilitates the exchange of power system data between utilities. In the paper [12] an example of porting by means of DLLs with the simulation software EMTP-RV and Simulink is presented.

The main difficulty common to all three methods is the lack of a standard defining the necessary calls and information exchange between model and simulation software.

In this study we will focus on the method related to DLLs, as the main simulation software already provides the possibility to integrate models in this format.

On a standard for the structure of DLLs, [13] describes the most popular one in this field, IEC 61400-27-1 [14]. This standard defines which functions should be included in the DLL, the order and how they are called. The main functions are:

- Model_Getinfo() providing general information about the model.
- Model_Instance() creating the instance of the model (multi-instancing is supported).
- Model_Initialize() initializing the model.
- Model_Outputs() performing simulation time step giving model outputs.
- Model_Terminate() shutting down a specified model instance.

Following the structure of this standard, the Multilink tool [15] was created, which gives the possibility to integrate models written in code following the IEC 61400-27-1 standard in different simulation software.

The aim of this work is to analyse the integration of a model in different simulation software based on a common code, in order to compare the results of the same simulated event and to draw conclusions on the advantages and limitations. By way of example, this work analyses how to develop a code model following the IEC 61400-27-1 standard and its implementation in three of the main simulation softwares, Matlab Simulink [16], PSCAD [17] and DigSilent PowerFactory [18], using the Multilink tool, in order to compare the results obtained.

The first step followed for this research was the creation of a model following the IEC 61400-27-1 standard. Subsequently, this model was integrated into Matlab Simulink to check the correct operation of the code, before integrating it into PSCAD and DigSilent. Finally, the simulation scenario was defined and the results obtained in the three chosen simulation software applications were compared.

2. EMT model

Using C++ language and the Visual Studio v2019 tool, a simple inverter model has been developed for EMT simulations in accordance with the IEC 61400-27-1 standard. The structure of this model is shown in Fig. 1. As can be seen, the model takes as input the voltage and current measurements per phase, the frequency and the active and reactive power setpoints desired by the user. The outputs of the model are the currents per phase, which will be fed to a current source, and the active and reactive power measurements calculated by the model from the voltage and current inputs. These active and reactive power signals will be used for the final comparison.

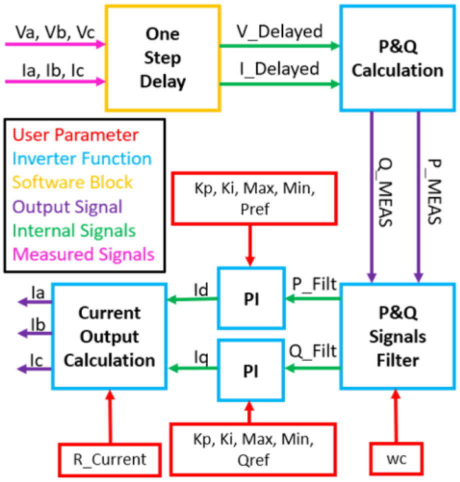

Fig. 1. Inverter EMT model signals diagram.

The user also defines at the start of the simulation the values to be given to the PI controller parameters.

3. Model Integration

The simulation tools chosen for this EMT simulation study were DigSilent PowerFactory, Matlab Simulink and PSCAD. The choice of these three platforms was based on the fact that these are the three main tools used in the electrical power systems sector for carrying out EMT simulations.

To integrate the model in PSCAD, it only gives the option of doing so as a DLL file, while Simulink and DigSilent give the possibility of DLL and FMU (Functional Mock-Up). FMU is a free standard for exchanging dynamic simulation models that consists of combining the DLL file with an XML file, where the characteristics of the inputs, outputs and parameters of the DLL model are defined [19].

In DigSilent, it was necessary to wait until version 2022 for the DLL to be called only at a fixed simulation step, and only by integrating the model by FMU.

When integrating the model using FMU in DigSilent, problems appeared with reading the DLL, instability of the model outputs and differences with what was obtained with DLL in Simulink. The model was simplified by removing the load flow initialisation part due to the fact that at each simulation step the solver called the Model_Initialize function when integrating the model as FMU, not only in the first step. In an attempt to obtain the most similar response possible with both model integration methods, a simulation is carried out in Simulink with the same scenario and both methods. The simulation consisted of changing the active and reactive power setpoints and the results are shown in Fig. 2 (active power) and Fig. 3 (reactive power).

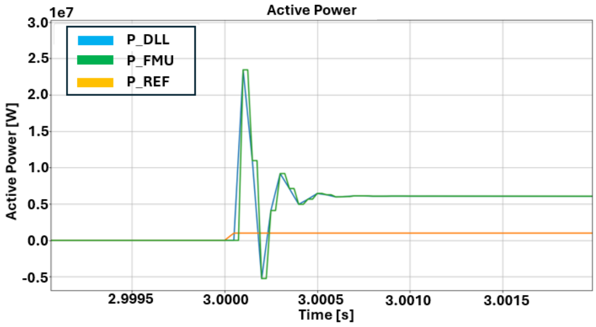

Fig. 2. Active power measured signal with DLL (blue) and FMU (green) model integration in Simulink.

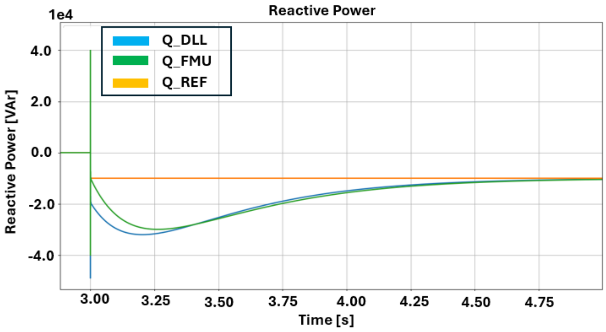

Fig. 3. Reactive power measured signal with DLL (blue) and FMU (green) model integration in Simulink.

The active power signal obtained in both simulations is the same, while the reactive power signal shows a small difference, the peak being higher at the time of the setpoint change in the DLL simulation.

With these results, the integration of the model in PSCAD and DigSilent is carried out.

4. Simulation scenario

The simulation scenario chosen to be replicated in Simulink, PSCAD and DigSilent consists of a three-phase voltage source, followed by an RL impedance and finally the current sources with a parallel resistor. Voltage and current measurements are taken at the output of the current source, in the direction of the voltage source.

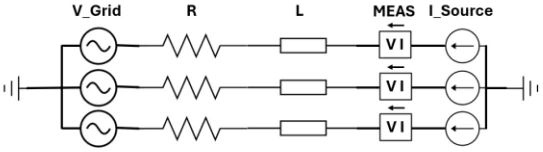

Fig. 4. Simulation scenario diagram.

The simulation step used is 50 microseconds.

The versions of the tools used are shown in Table I.

Table I. – Tools versions.

TOOL	VERSION
Visual Studio	2019
Matlab Simulink	R2020b
DigSilent PowerFactory	2022
PSCAD	4.6.2

5. Software differences

This section shows the main differences found in the modelling of the system between these three simulation tools.

A. Matlab Simulink

The model is integrated as a DLL file, although it is also possible to do it as an FMU.

It is necessary to apply a delay on the input signals which are measurements of voltage and current. The delay applied is one simulation step, 50 microseconds.

The current source receives the setpoints in amperes.

The resistance parallel to the current source is modelled externally to the Simulink current source model itself.

The discrete equation solver used by Simulink is the Tustin method.

B. PSCAD

The model is integrated as a DLL file, compiled as Release Win32.

It is not necessary to apply a delay on the input signals, which are voltage and current measurements.

The current source receives the setpoints in kiloamperes.

The resistor parallel to the current source is modelled externally to the PSCAD current source model, following the direction used for MATLAB.

The resolution method used by PSCAD is trapezoidal.

C. DigSilent

The model is integrated as an FMU file.

It is necessary to apply a delay on the input signals which are measurements of voltage and current. The delay applied is one simulation step, 50 microseconds.

By default, the voltage source is initialised with phase A at its maximum value. An offset of -90° must be applied.

The current source receives the setpoints in kiloamperes and it is necessary to change the sign of these setpoints at its input.

The current source model has the option of placing a resistor in parallel, but its sense is different to that expected in the code and to that modelled in PSCAD and Simulink. Therefore, the sign of the part of the equation referring to the compensation of the current passing through this resistor must be changed.

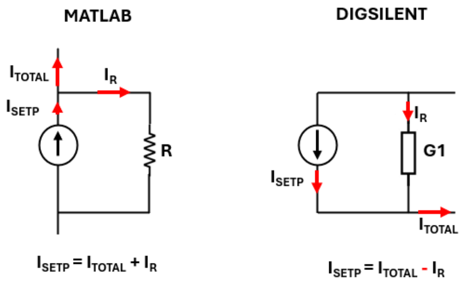

Fig. 5. Current source parallel resistance representation.

DigSilent gives the option to use either Backward Euler or Trapezoidal as the resolution method by setting the "Damping factor" parameter (0=Backward Euler; 1= Trapezoidal). A value of 1 is given.

6. Results

The simulation consisted of modifying the active and reactive power setpoints, as shown in Table II.

Table II. - Simulation events.

TIME [S]	SIGNAL	VALUE	UNIT
0.0	P_REF	0.0	W
0.0	Q_REF	0.0	VAr
9.0	P_REF	100000.0	W
9.0	Q_REF	-100000.0	VAr
15.0	P_REF	0.0	W
15.0	Q_REF	0.0	VAr

The signals compared are the powers measured by the inverter model in W and Var, together with the setpoint.

In Fig. 6, Fig. 7 and Fig. 8, the active power signals are shown, progressively zooming in on the time axis. The DigSilent signal is shown in orange, the Simulink signal in green and the PSCAD signal in red.

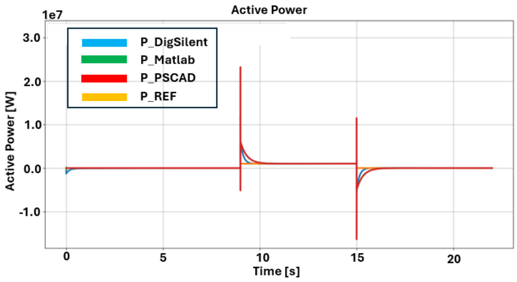

Fig. 6. All simulation active power signals.

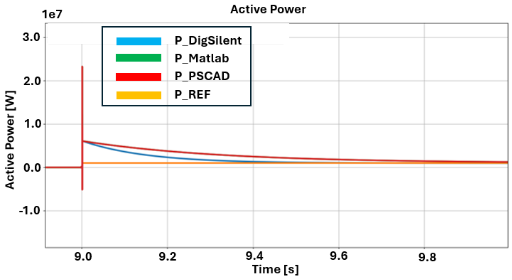

Fig. 7. Active power time to reach the setpoint value.

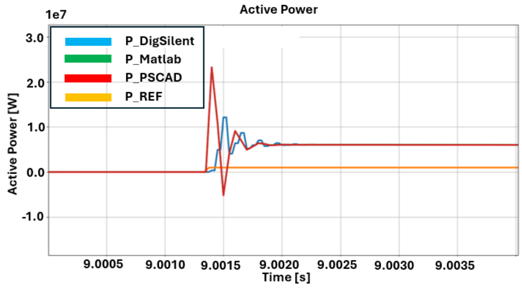

Fig. 8. Active power at the instant of setpoint change.

It can be seen how the signals obtained in Simulink and PSCAD are exactly the same, while the signal obtained in DigSilent has a lower peak amplitude and reaches the desired value in less time than the signals from the other two software.

In steady state, the active power measured in Simulink has an error of 0.0085% with respect to the setpoint. Taking this measurement as a reference, the difference in steady state between the PSCAD and Simulink measurement is -0.00026% and between DigSilent and Simulink is 0.46%.

Fig. 9, Fig. 10 and Fig. 11 show the reactive power signals measured by the inverter model from the voltage and current input signals. The DigSilent signal is shown in orange, the Simulink signal in green and the PSCAD signal in red.

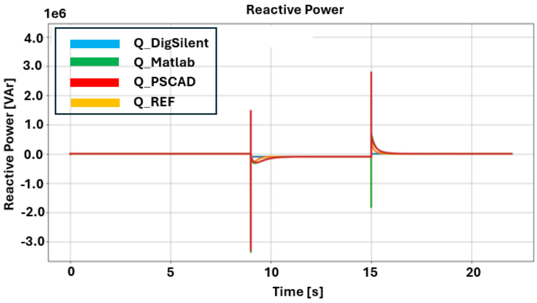

Fig. 9. All simulation reactive power signals.

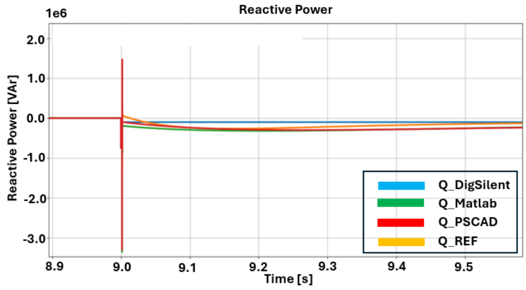

Fig. 10. Reactive power time to reach the setpoint value.

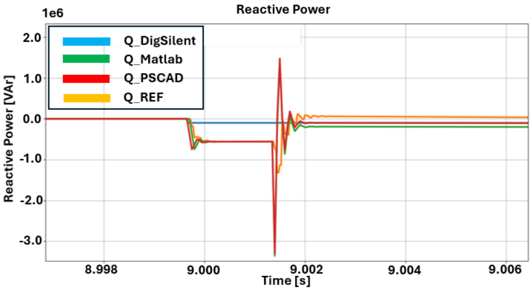

Fig. 11. Reactive power at the instant of setpoint change.

These figures show how the reactive power signals do not take the same values in the three simulation tools for the same setpoint change. The PSCAD and Simulink signals (red and green) have small differences during the transient and the time taken to reach the defined setpoint is the same. As for the response in DigSilent, the amplitude during its transient is smaller and the time taken to reach the setpoint is shorter than in the other two software applications.

In steady state, the reactive power measured in Simulink has an error of 0.00021% with respect to the setpoint. Taking this measurement as a reference, the difference in steady state between the PSCAD and Simulink measurement is 0.00019% and between DigSilent and Simulink is 0.54%.

7. Conclusions

After the creation of a simple inverter model following the structure established by the IEC 61400-27-1 standard, the Multilink tool has enabled its integration into Matlab Simulink, DigSilent and PSCAD software.

With the simulation in Simulink of the model, integrating it as a DLL file and as an FMU file, it was verified how differences appeared in the call to the model from Simulink. The main difference in the treatment of the model with respect to one integration method or the other is the call to the Model_Initialize function in all the simulation steps when integrating the model using FMU. From these results it was found that the result in active power was the same, but differences appeared in the reactive power signal.

The model has been successfully integrated into the three simulation tools for the execution of an EMT simulation by recreating the same scenario in the three software for a later comparison.

With respect to the comparison of the results obtained, it can be seen that the active power signal is the same in Simulink and PSCAD, while the DigSilent signal has a lower peak amplitude during the transient and takes less time to reach the desired setpoint.

The results obtained for reactive power show that the PSCAD and Simulink signals have small differences during the transient and the time taken to reach the defined setpoint is the same. As for the response in DigSilent, the amplitude during its transient is smaller and the time taken to reach the setpoint is shorter than in the other two software applications.

With the results obtained, the capacity of the Multilink tool for the integration of the same model in different simulation software has been tested. The tests with this tool should continue, extending the number of simulations with short-circuit tests and with a new model and RMS simulations. This can be very useful for saving time in the development of models and for a better version control, by having a single model for all the software.

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