TASK 1.5: DYNAWO INITIAL STUDIES

Chapter 1

A comparison between Modelica and Simulink models. Four different test cases regarding ENTSO-E_131127_Controller_Test_Report. The tests are summarised only with the relevant results.

Chapter 2

A VSC model is implemented and tested. The issues encountered with Dynawo are summarized.

Chapter 1

TEST CASE 1

A comparison of the dynamic behaviour of the model for the synchronous machine and its AVR. The generator is operated in a no-load operation. At the event time, the reference value for the terminal voltage is increased by + 0.05 pu. The stabiliser is switched off. The terminal voltage UNGEN and the exciter voltage EFD are analysed.

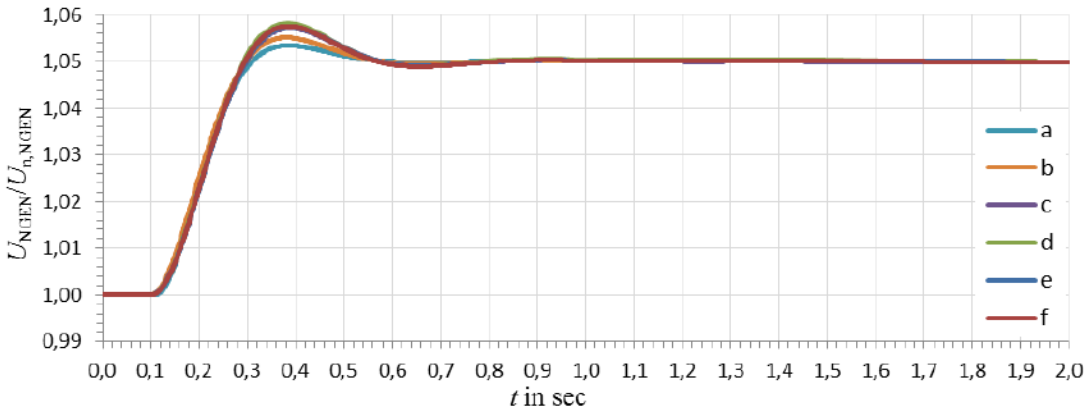
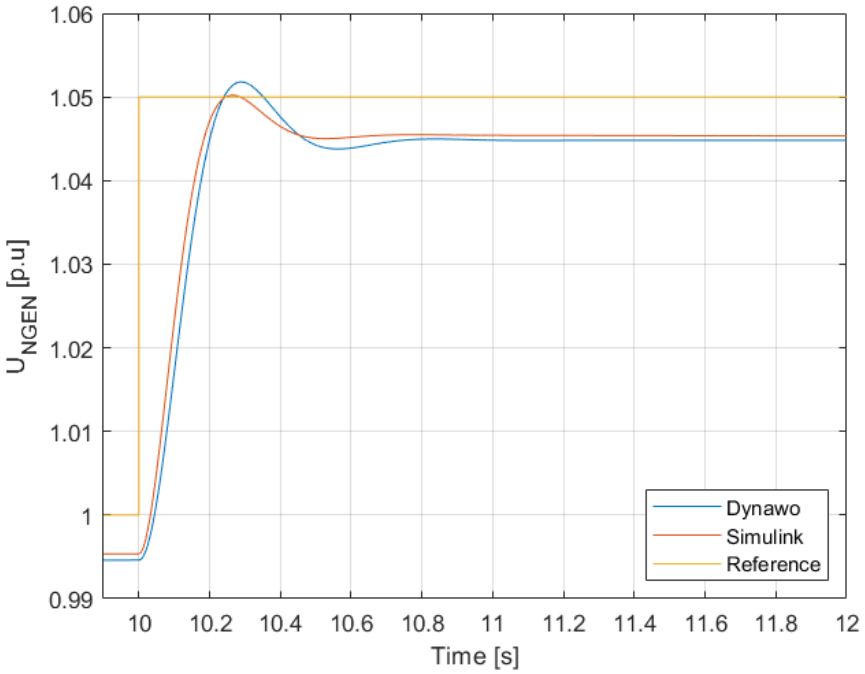


FIG. 5-1: RESPONSE OF TERMINAL VOLTAGE OF MACHINE IN TEST CASE 1



Notice that Dynawo response is about 0.2 seconds slower. There exists a difference of 5e-3 pu between the terminal voltage and the reference value at steady-state in both cases.

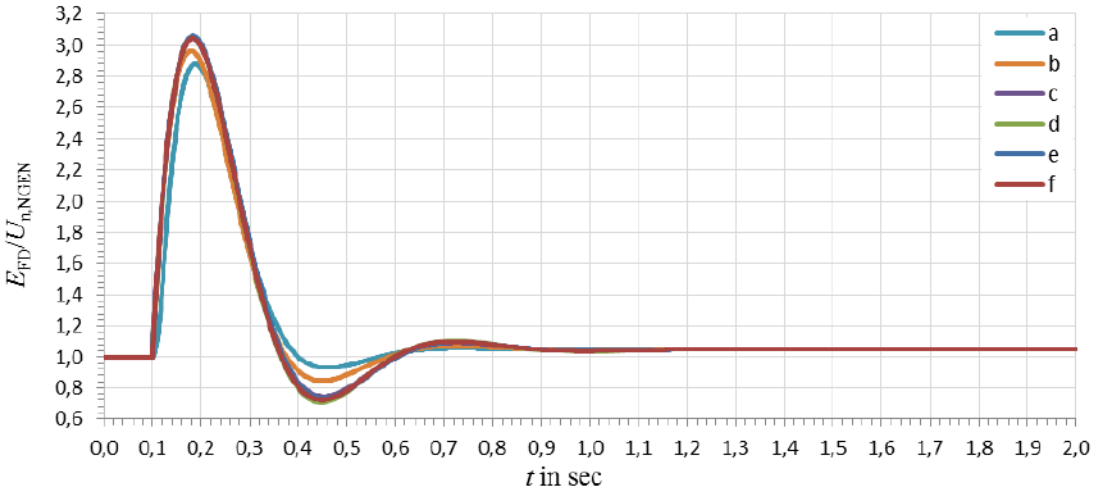
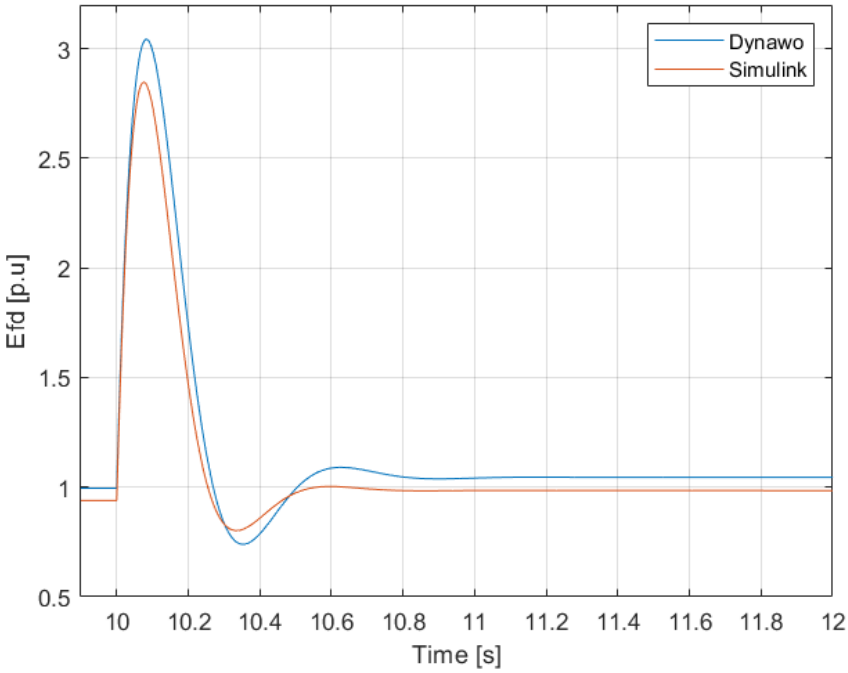


FIG. 5-2: RESPONSE OF EXCITATION VOLTAGE OF MACHINE IN TEST CASE 1



In Dynawo, the excitation voltage settling time is about 0.2 seconds higher than Simulink and oscillates sligthly more.

TEST CASE 2

A constant impedance is implemented at the node NGEN. The stabiliser is switched off. The initial active power demand in the constant impedance of $P_L = 0.8 \cdot S_{r,G} \cdot \text{cosfi} = 380$ MW. At the event-time, the additional constant impedance's active power demand is increased by ΔPL = + 0.05 pu. ($P_{r,G} = \cdot S_{r,G} \cdot \text{cosfi} = 475$MW).

In the Modelica model the $S_{base,gen}$ is set at 500 MVar and the PNomAlt at 475MW. In Simulink model the $S_{base,gen}$ is set at 475MVar,

Comparison of the dynamic behaviour of the model for the synchronous generator and its governor by analysing the terminal voltage U_{NGEN}, the active and mechanical power of the SG P_G and P_{MECH}, and the speed ω_G.

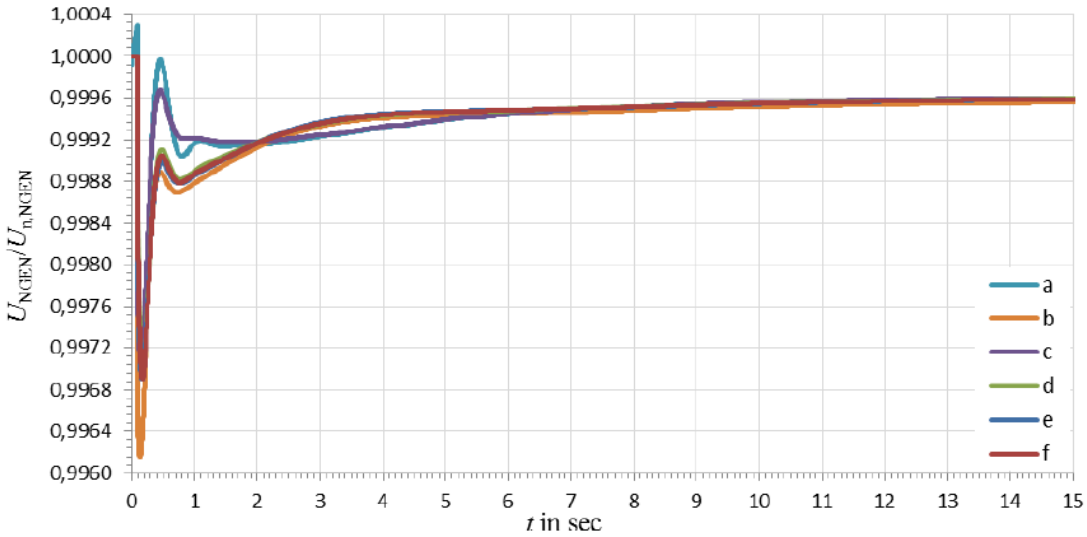
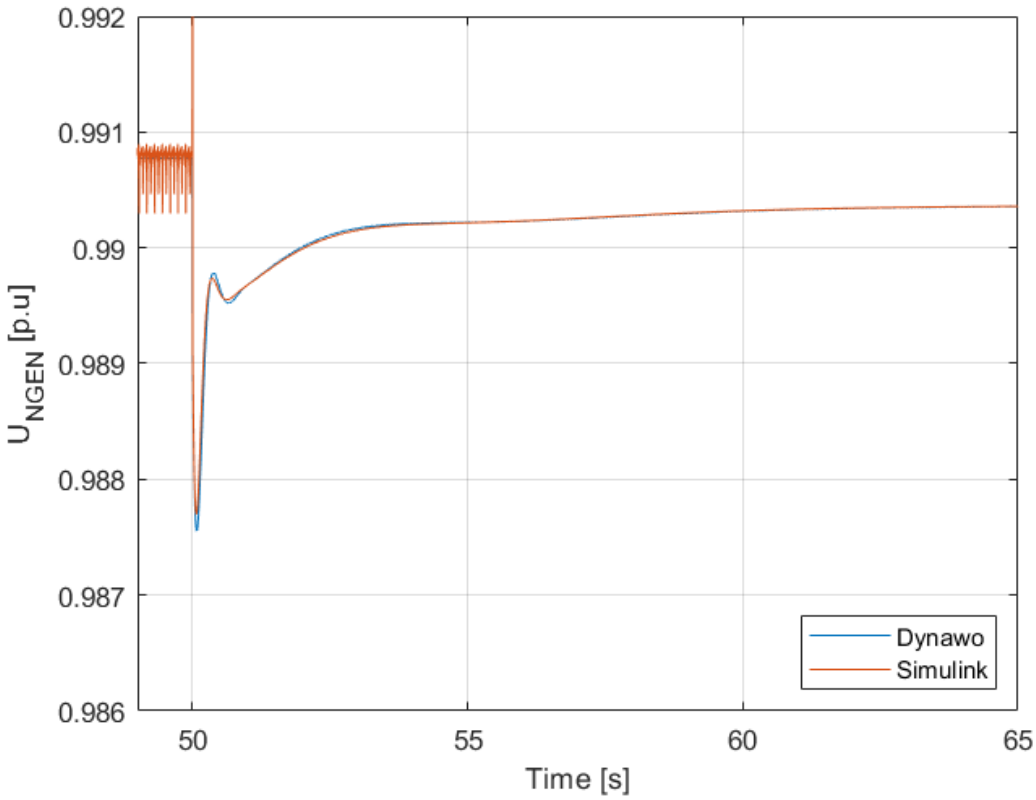


FIG. 5-3: RESPONSE OF TERMINAL VOLTAGE OF THE MACHINE IN TEST CASE 2



The response of the terminal voltage of both models matches. Notice that before the load variation, there exists some noise in the Simulink model. Probably due to the use of a fixed step size solver. When working with dynamic loads, if the simulation is carried out with a variable step size solver, the simulation is too slow, about 30 minutes.

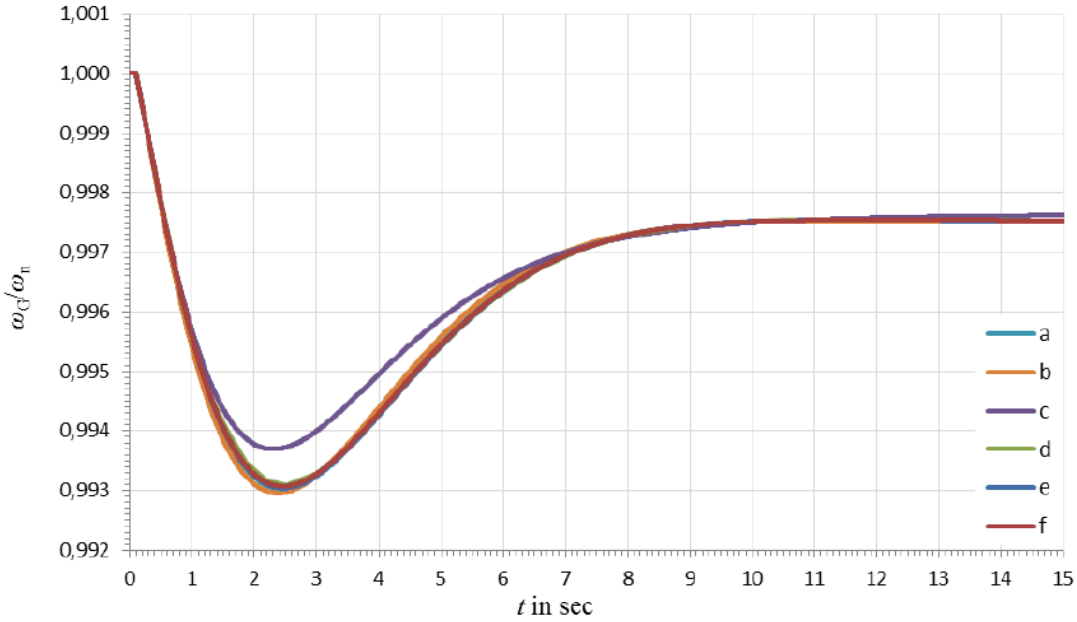
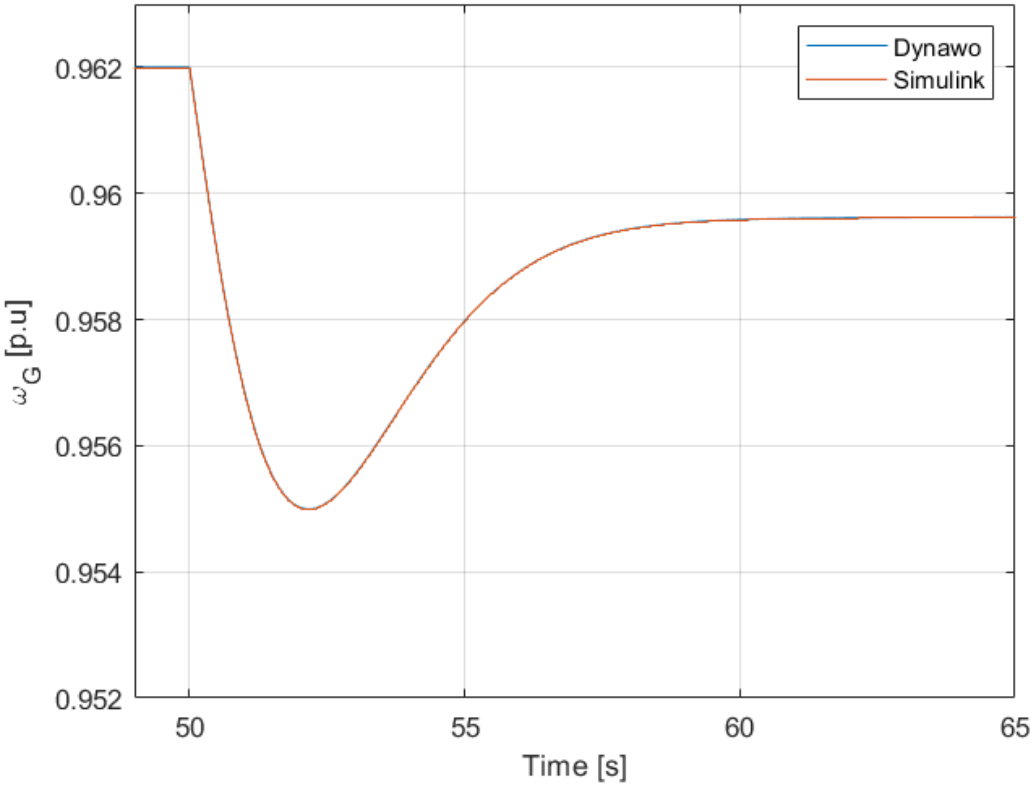


FIG. 5-6: RESPONSE OF MACHINE SPEED IN TEST CASE 2



The speed shows a good response for both models.

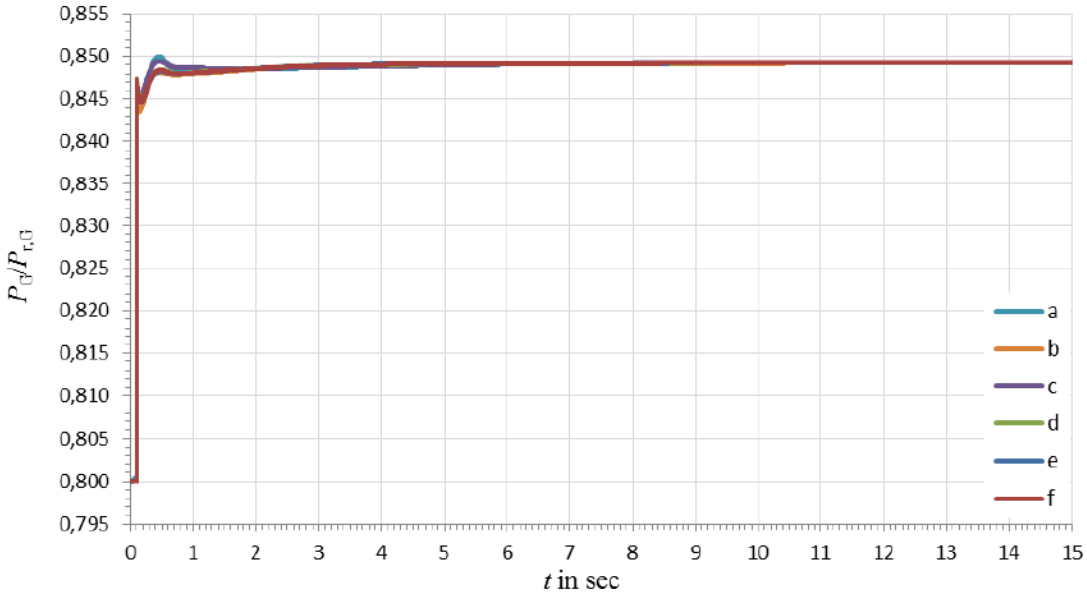
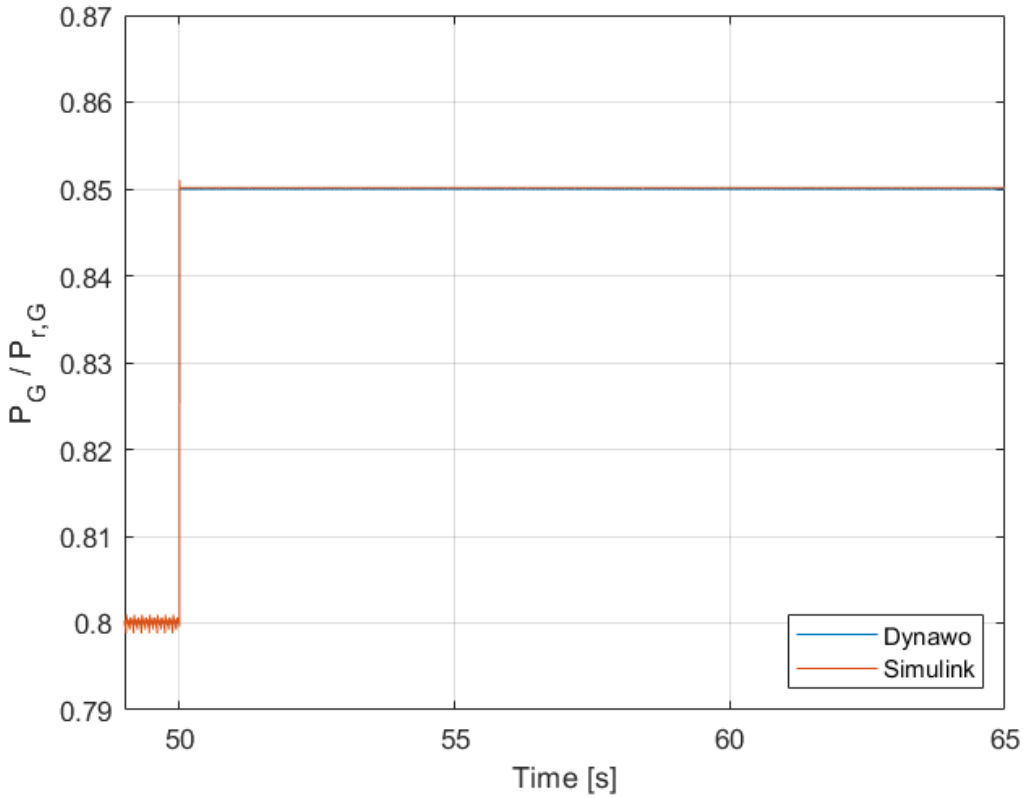


FIG. 5-4: RESPONSE OF ACTIVE POWER OF THE MACHINE IN TEST CASE 2



The generated power shows a good response for both models. Before the load variaton some noise can be observed due to the issue commented previously.

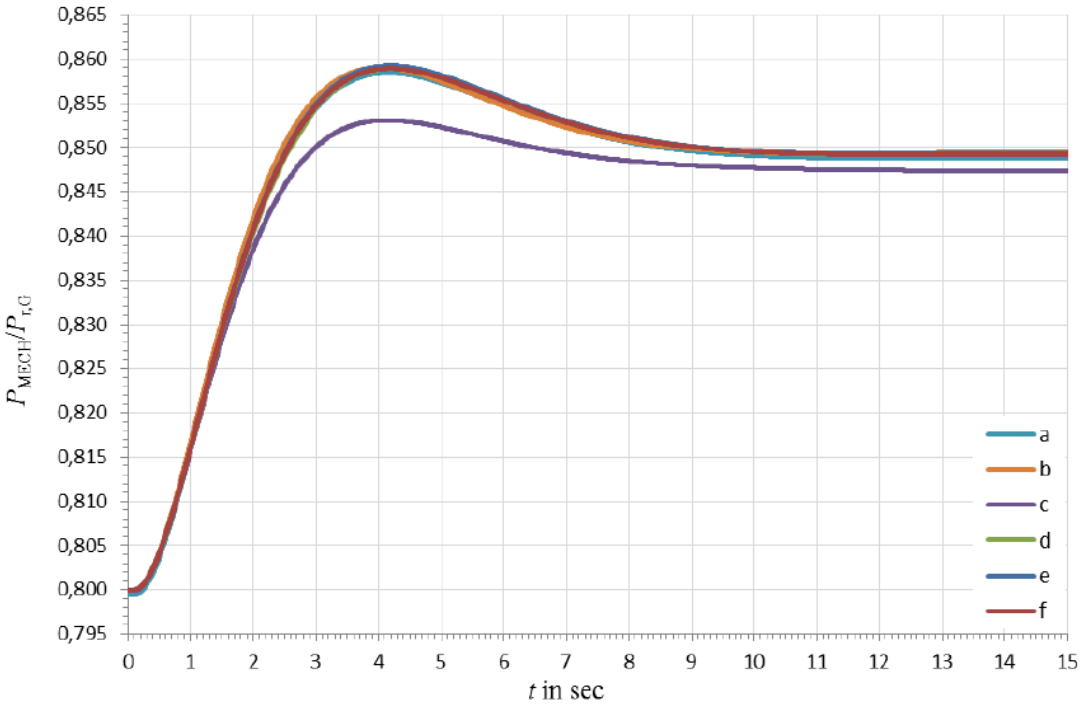
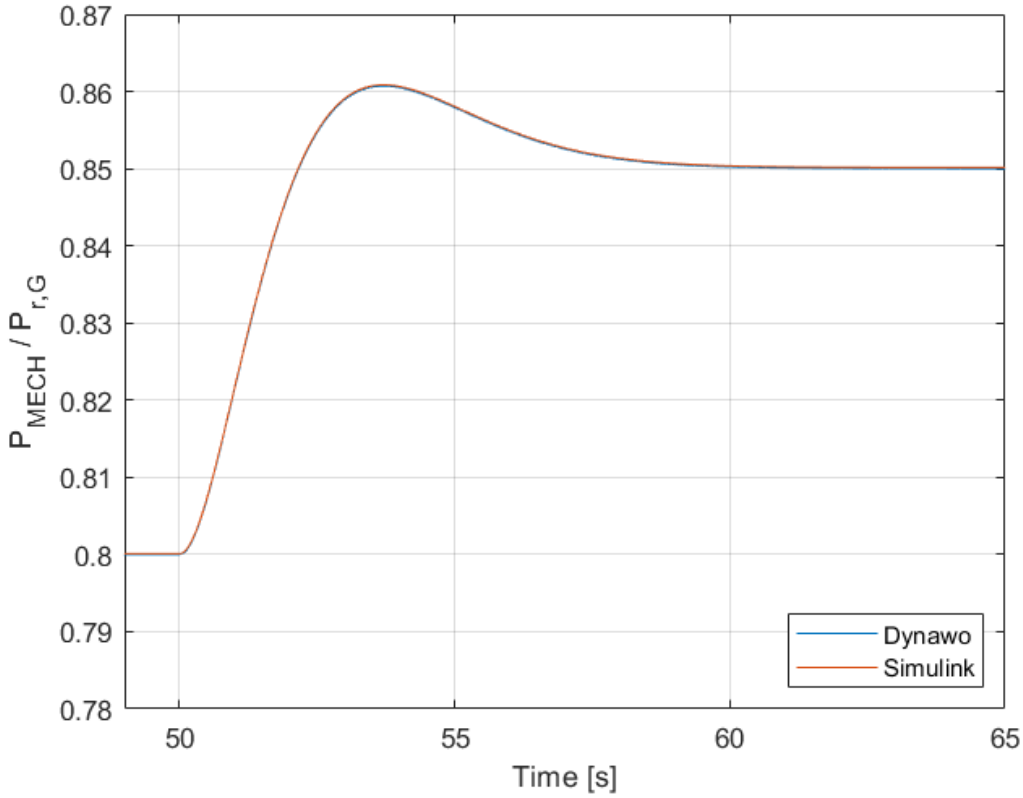


FIG. 5-5: RESPONSE OF MECHANICAL POWER OF MACHINE IN TEST CASE 2



The mechanical power shows a good response for both models.

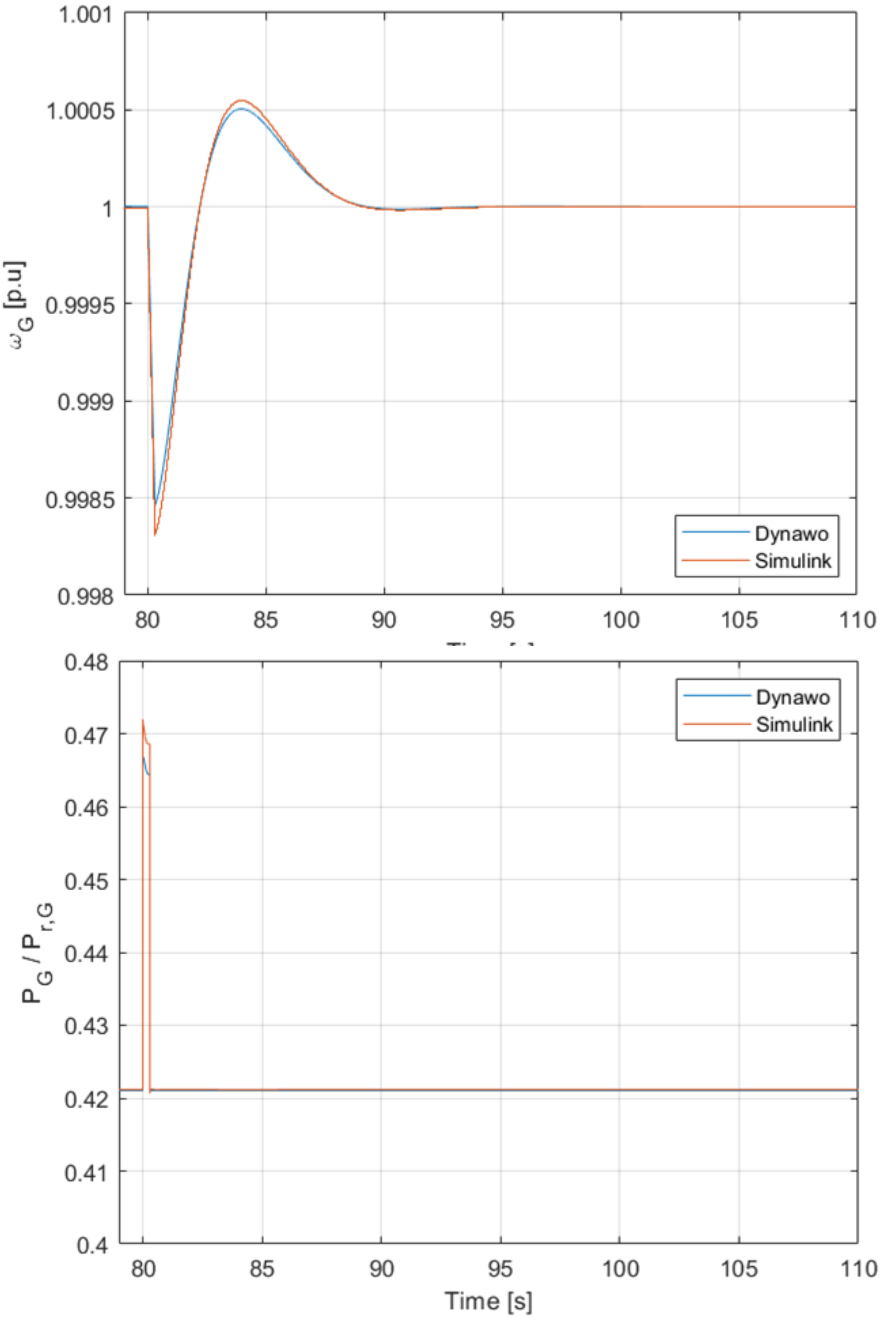
TEST CASE 3

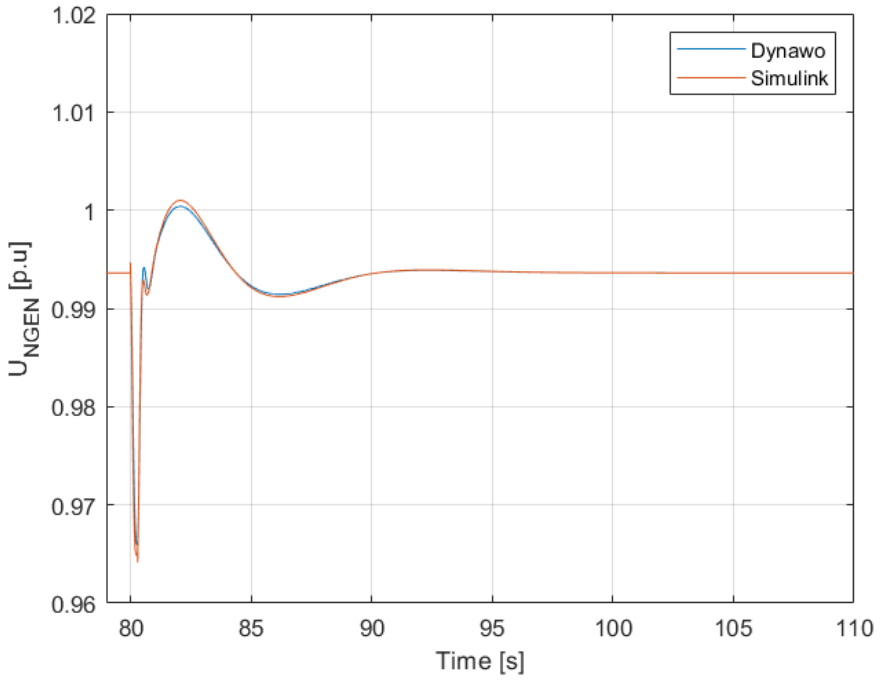
In this test, a 1 Ohm three-phase fault is simulated.

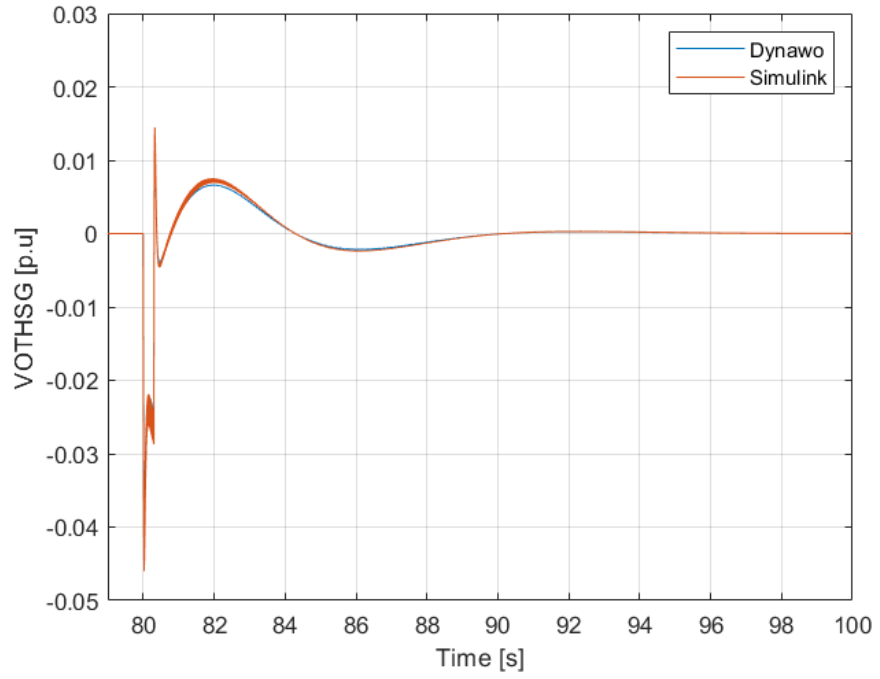
Test case 3 has been only performed in Simulink. In Dynawo, the solver cannot deal with the low fault resistance value. Fault resistances of about 1 to 7 ohms could be used on the high voltage side. However, to carry out the simulation in Dynawo, at least about 40 Ohms are needed.

TEST CASE 4

In this test, the synchronous generator is connected to a 200 MW load (at MV). The dynamic behaviour of the synchronous machine with its complete control in operation after a three-phase short-circuit is analysed by observing the terminal voltage U_{NGEN}, the generated active power P_G, the speed ω_G, and the PSS output signal VOTHSG. The fault duration is 300 ms—fault resistance of 20 Ohms.





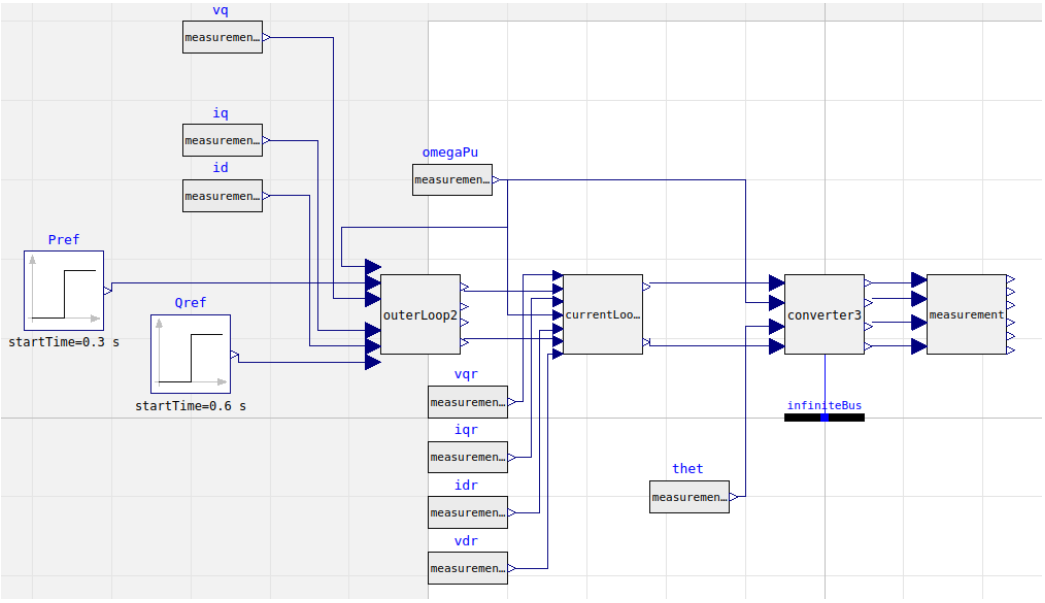


The speed, generated active power, terminal machine voltage, and PSS output signal of both models match. The systems show a good response.

Chapter 2

PQ set point tracking

A VSC model (same as the phasor VSC model from Vinicius in Simulink) is implemented in Modelica. For a better comparison of the VSC control, the converter terminal is simply connected to an infinite bus.



The model is correctly built. At compilation, there is the same number of equations as variables. In OpenModelica, the simulation works fine.

The problem occurs when the solver starts to handle the global initialisation of the model. It is not an initial equations issue; the initial equations are related only to the initial variables. The default linear solver is KLU. The other alternative is to use NICSLU but it is not recognised?? the linear solver name provided is not valid (DYNSolverKINCommon.cpp:154). Ten more variables than equations.

Using IDA solver

```
2021-02-24 20:10:10 | INFO |  ================================================================
2021-02-24 20:10:10 | INFO | DYNAWO VERSION  :     1.3.0
2021-02-24 20:10:10 | INFO | DYNAWO REVISION :    master-7d6aa438
2021-02-24 20:10:10 | INFO |  ================================================================
2021-02-24 20:10:10 | INFO |
2021-02-24 20:10:10 | INFO | ------------------------------------------------------------------------
2021-02-24 20:10:10 | INFO | building model from input files
2021-02-24 20:10:10 | INFO | ------------------------------------------------------------------------
2021-02-24 20:10:48 | INFO | model was built successfully
2021-02-24 20:10:48 | INFO | ------------------------------------------------------------------------
2021-02-24 20:10:48 | INFO |
2021-02-24 20:10:48 | INFO | ------------------------------------------------------------------------
2021-02-24 20:10:48 | INFO | starting local initialization
2021-02-24 20:10:48 | INFO | ------------------------------------------------------------------------
2021-02-24 20:10:48 | INFO | end of local initialization
2021-02-24 20:10:48 | INFO | ------------------------------------------------------------------------
2021-02-24 20:10:48 | INFO |
2021-02-24 20:10:48 | INFO | ------------------------------------------------------------------------
2021-02-24 20:10:48 | INFO | starting global initialization
2021-02-24 20:10:48 | INFO | ------------------------------------------------------------------------
2021-02-24 20:10:48 | ERROR | variables number 72 not equals to the equations number 62 ( DYNSolverImpl.cpp:116 )
```

(DYNSolverImpl.cpp:116)

// Problem size

```
// ---------------------------
// Continuous variables
int nbEq = model->sizeY(); nbEq == number of equations, sizeY() and sizeF() ??
if (nbEq != model->sizeF())
        throw DYNError(Error::SUNDIALS_ERROR, SolverYvsF, nbEq, model->sizeF());
```

Using simplified solver

error during the call of KINSOL's function (SUNLinSol_KLU) (DYNSolverKINCommon.cpp:140)

```
if (linearSolverName_ == "KLU") {
        LS_ = SUNLinSol_KLU(yy_, M_); meaning LS_ = 0 ??
        if (LS_ == NULL)
        throw DYNError(Error::SUNDIALS_ERROR, SolverFuncErrorKINSOL, "SUNLinSol_KLU");
```

---

*SUNLinearSolver **LS_**; ///< Linear Solver pointer*

*SUNMatrix **M_**; ///< sparse SUNMatrix*

*N_Vector **yy_**; ///< variables values stored in Sundials structure*

Possible solutions thoughts

- Regarding the dyd file

i) We have tried several ways to write the dyd file regarding control loops' connections – converter, same compilation. Ok

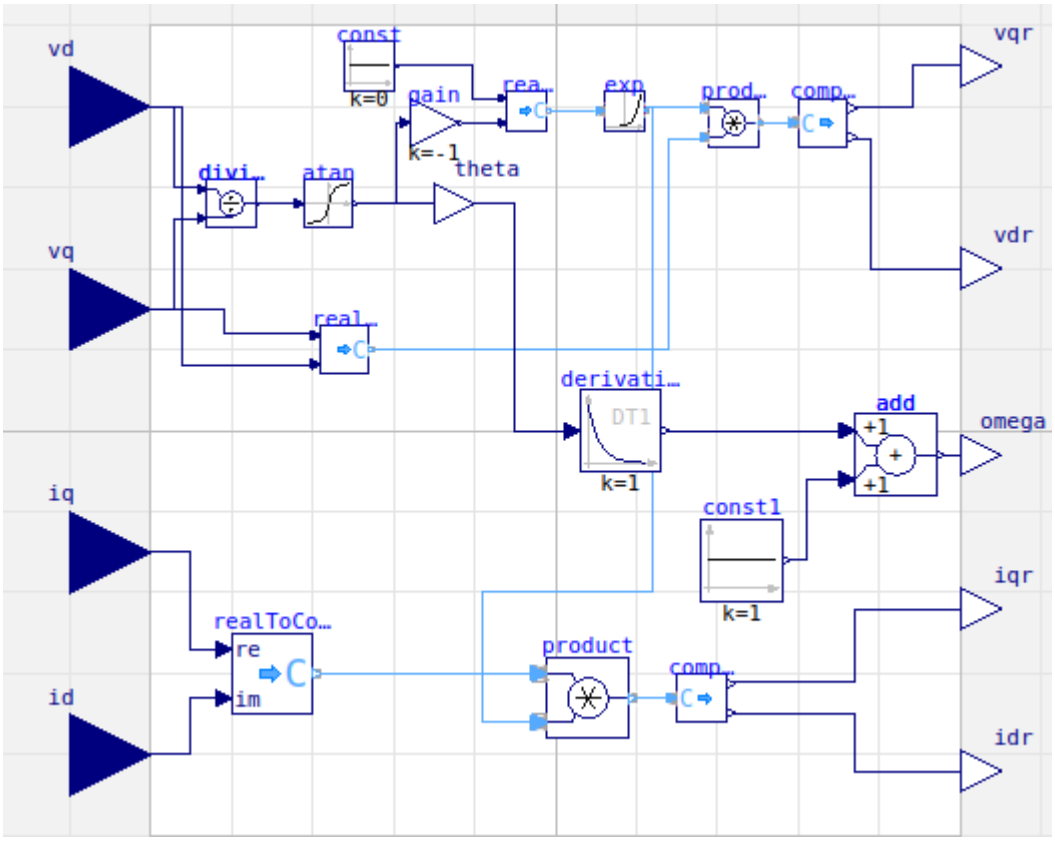
ii) To check if it happened the same with the Dynawo Modelica models library, we have tried to simulate in Dynawo the GridForming Modelica model example from the Dynawo Modelica library. However, we observe the same 'kind of' issue. Maybe we should consider the *iidm* file to complete the remaining needed equations?

*dynawo.log

```
 1 2021-03-05 15:06:04 | INFO |  ============================================================
 2 2021-03-05 15:06:04 | INFO | DYNAWO VERSION  :     1.3.0
 3 2021-03-05 15:06:04 | INFO | DYNAWO REVISION :    master-7d6aa438
 4 2021-03-05 15:06:04 | INFO |  ============================================================
 5 2021-03-05 15:06:04 | INFO |
 6 2021-03-05 15:06:04 | INFO | ------------------------------------------------------------------------
 7 2021-03-05 15:06:04 | INFO | building model from input files
 8 2021-03-05 15:06:04 | INFO | ------------------------------------------------------------------------
 9 2021-03-05 15:06:04 | INFO | model was built successfully
10 2021-03-05 15:06:04 | INFO | ------------------------------------------------------------------------
11 2021-03-05 15:06:04 | INFO |
12 2021-03-05 15:06:04 | INFO | ------------------------------------------------------------------------
13 2021-03-05 15:06:04 | INFO | starting local initialization
14 2021-03-05 15:06:04 | INFO | ------------------------------------------------------------------------
15 2021-03-05 15:06:04 | DEBUG | ------------------------------
16 2021-03-05 15:06:04 | DEBUG | starting local initialization of model Droop
17 2021-03-05 15:06:04 | DEBUG | local initialization of model Droop ended successfully
18 2021-03-05 15:06:04 | DEBUG | ------------------------------
19 2021-03-05 15:06:04 | DEBUG | starting local initialization of model Load
20 2021-03-05 15:06:04 | DEBUG | local initialization of model Load ended successfully
21 2021-03-05 15:06:04 | DEBUG | ------------------------------
22 2021-03-05 15:06:04 | DEBUG | starting local initialization of model Matching
23 2021-03-05 15:06:04 | DEBUG | local initialization of model Matching ended successfully
24 2021-03-05 15:06:04 | DEBUG | ------------------------------
25 2021-03-05 15:06:04 | DEBUG | starting local initialization of model dVOC
26 2021-03-05 15:06:04 | DEBUG | local initialization of model dVOC ended successfully
27 2021-03-05 15:06:04 | INFO | end of local initialization
28 2021-03-05 15:06:04 | INFO | ------------------------------------------------------------------------
29 2021-03-05 15:06:04 | INFO |
30 2021-03-05 15:06:04 | INFO | ------------------------------------------------------------------------
31 2021-03-05 15:06:04 | INFO | starting global initialization
32 2021-03-05 15:06:04 | INFO | ------------------------------------------------------------------------
33 2021-03-05 15:06:04 | ERROR | variables number 310 not equals to the equations number 323 ( DYNSolverImpl.cpp:116 )
```

- Regarding the VSC modelling.

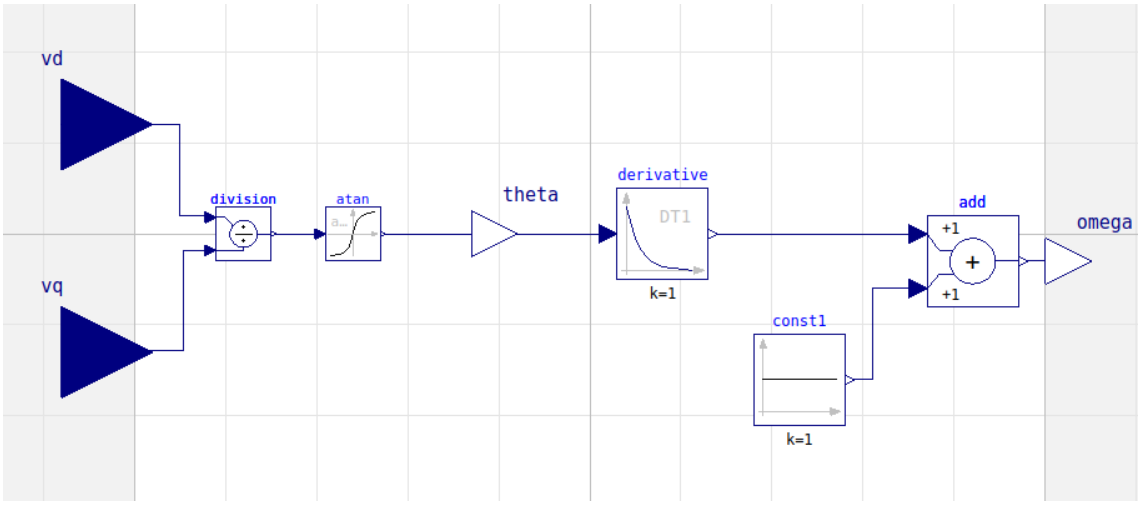
If we change the 'measurements block' (used to align the *vd* component at 0, we are using the *qd0* reference frame) for the two following alternatives, we can run the simulation. However, the goal is to compare the same models in Simulink and Dynawo. To validate the Modelica models, both models must be the same.



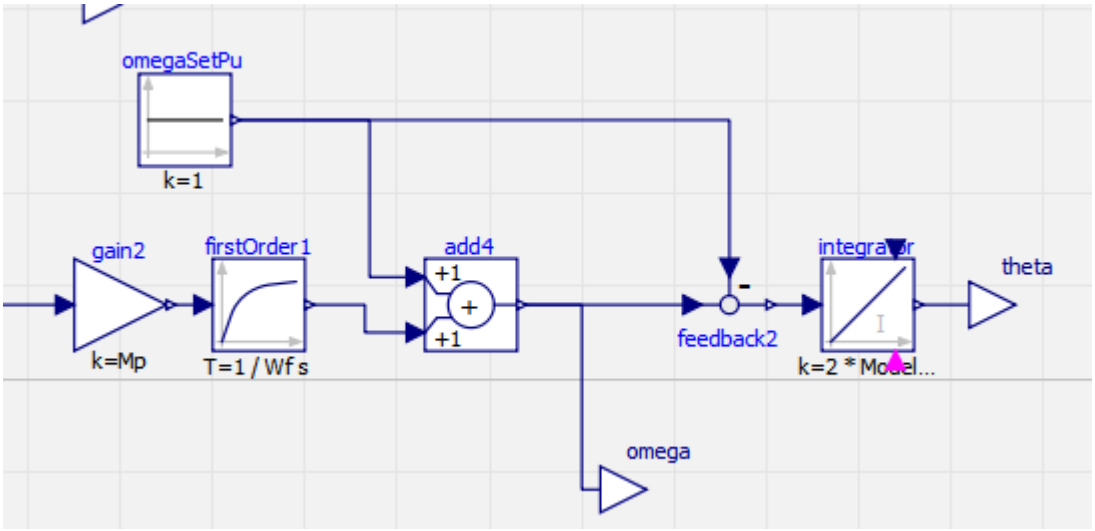
i) Measure *omega* and *theta* and calculate the active and reactive power as:

P = vq*iq + vd*id

Q = vq*id – vd*iq



ii) Consider a frequency droop due to (Pref – Pmeasured) to recalculate omega and *theta*.



iii) written equations alternative to RealToComplex/ComplexToReal blocks. In OpenModelica, both models are equivalent.

```
model Measurements2
  import Modelica;
  import ComplexMath;
  Modelica.Blocks.Interfaces.RealOutput iqr annotation( ...);
  Modelica.Blocks.Interfaces.RealInput vd annotation( ...);
  Modelica.Blocks.Interfaces.RealOutput vdr annotation( ...);
  Modelica.Blocks.Interfaces.RealOutput idr annotation( ...);
  Modelica.Blocks.Interfaces.RealInput iq annotation( ...);
  Modelica.Blocks.Interfaces.RealInput id annotation( ...);
  Modelica.Blocks.Interfaces.RealOutput vqr annotation( ...);
  Modelica.Blocks.Interfaces.RealInput vq annotation( ...);
  Modelica.Blocks.Interfaces.RealOutput omega annotation( ...);
  Modelica.Blocks.Interfaces.RealOutput theta annotation( ...);
  Complex v;
  Complex i;
  Complex pv;
  Complex pi;

 equation
  v = Complex(vq,vd);
  i = Complex(iq,id);

  if vd == 0 and vq == 0 then
    theta  = 0;
    pv = v * Modelica.ComplexMath.exp(-Complex(0,1)*theta);
    vqr = Modelica.ComplexMath.real(pv);
    vdr = Modelica.ComplexMath.imag(pv);
    pi = i * Modelica.ComplexMath.exp(-Complex(0,1)*theta);
    iqr = Modelica.ComplexMath.real(pi);
    idr = Modelica.ComplexMath.imag(pi);
    omega = der(theta) + 1;

  else
    theta = Modelica.Math.atan(vd/vq);
    pv = v * Modelica.ComplexMath.exp(-Complex(0,1)*theta);
    vqr = Modelica.ComplexMath.real(pv);
    vdr = Modelica.ComplexMath.imag(pv);
    pi = i * Modelica.ComplexMath.exp(-Complex(0,1)*theta);
    iqr = Modelica.ComplexMath.real(pi);
    idr = Modelica.ComplexMath.imag(pi);
    omega = der(theta) + 1;

  end if
 annotation( ...);
end Measurements2;
```

- Change from Dynawo 1.3.0 master-7d6aa438 to Dynawo 1.3.0 master-a5ca9fee. The simulation also fails.
- Could be that the RealToComplex/ComplexToReal are not supported by the linear solver yet, changed to ‘written’ equations measurements block. The solver is initialized correctly but the simulation also fails. In OpenModelica the simulation executes successfully both with ‘written equations’ and using RealToComplex/ComplexToReal blocks.

```
2021-03-18 10:40:55 | INFO |  ============================================================
2021-03-18 10:40:55 | INFO | DYNAWO VERSION  :     1.3.0
2021-03-18 10:40:55 | INFO | DYNAWO REVISION :    master-a5ca9fee
2021-03-18 10:40:55 | INFO |  ============================================================
2021-03-18 10:40:55 | INFO |
2021-03-18 10:40:55 | INFO | ------------------------------------------------------------------------
2021-03-18 10:40:55 | INFO | building model from input files
2021-03-18 10:40:55 | INFO | ------------------------------------------------------------------------
2021-03-18 10:41:52 | INFO | model was built successfully
2021-03-18 10:41:52 | INFO | ------------------------------------------------------------------------
2021-03-18 10:41:52 | INFO |
2021-03-18 10:41:52 | INFO | ------------------------------------------------------------------------
2021-03-18 10:41:52 | INFO | starting local initialization
2021-03-18 10:41:52 | INFO | ------------------------------------------------------------------------
2021-03-18 10:41:52 | INFO | end of local initialization
2021-03-18 10:41:52 | INFO | ------------------------------------------------------------------------
2021-03-18 10:41:52 | INFO |
2021-03-18 10:41:52 | INFO | ------------------------------------------------------------------------
2021-03-18 10:41:52 | INFO | starting global initialization
2021-03-18 10:41:52 | INFO | ------------------------------------------------------------------------
2021-03-18 10:41:52 | DEBUG | initialization of SIM solver : ok
2021-03-18 10:41:52 | DEBUG | calculate initial condition of the DAE
2021-03-18 10:41:52 | DEBUG | Algebraic mode change for model CONVERTER at t = 0
2021-03-18 10:41:52 | INFO | Algebraic mode change at t = 0
2021-03-18 10:41:52 | ERROR | the number of algebraic/differential variables is different from the number of algebraic/differential equations in the
simulated problem ( DYNSolverKINAlgRestoration.cpp:149 )
```