SAFER2028-SINARP Deliverable report,

D2.1.1: The 400 kV transmission system model (T2.1)

January 2024

John Millar
Floran Martin
Janne Seppänen
Marius Baranauskas
Ari Silde

John Millar, Floran Martin, Janne Seppänen, Aalto University, Marius Baranauskas and Ari Silde, VTT Research Centre of Finland

1 Introduction

The transmission model has undergone considerable upgrading and expansion, as mentioned in D1.1.1. It still falls short in at least two respects. Inertia is not properly modelled, in that the swing bus is a voltage source which supplies voltage support instantly after a contingency, thus compromising the realistic modelling of the transient behaviour of the grid and thus the impact on the nuclear power plants. Modelling the swing bus as a synchronous machine means the current model will not converge. Also, the demand is modelled as fixed P,Q loads, which no doubt also compromises the transient response during faults. The other is still some fine-tuning of the wind parks, but in this we are ahead of schedule, as 2023 was only intended to deliver a single wind-turbine model, but we have managed at least the first version of modelling full wind-parks, appropriately lumped to each relevant 400 kV connection point in the grid model. Olkiluoto 3 is now connected, and a few residential CHP generators in the south of Finland have also been added to the model. What remains, on the generator side, is better modelling of the synchronous machines, perhaps via digital twins to reduce simulation times, and continued effort to better model the power system stabilizers. All this, in addition to keeping up with the connection of new wind parks, photovoltaics, EV charging, and the projection of these activities into the future, will provide plenty of work in the next year or two, but the challenge is shifting the focus to impact on the NPPs, and we are mindful that continued activity in SAFER2028 is dependent on this.

2 The grid model as delivered for co-simulations at the end of 2023

The three LCC HVDC connections (Fennoscan 1 and 2, and Estlink2) have been developed ahead of schedule by Emma Reinikäinen, but were not implemented in the 2023 delivery. In fact when implementing everything we had developed in 2023, synchronous machine swing bus, HVDC connection and the wind parks led to instability in the grid, which will require more work in 2024. Fig. 1 shows the grid model, complete with commented out blocks still under development.

The new models that are in the current grid model are the wind turbine blocks, which are lumped to the appropriate 400kV connection points. Various HVDC blocks can be seen in the figure, but they have been commented out for present. Some further parametrisation would seem necessary. There have been several new connections added, and CHP generation units to more realistically cope with high demand mid-winter low wind scenarios.

John Millar, Floran Martin, Janne Seppänen, Aalto University, Marius Baranauskas and Ari Silde, VTT Research Centre of Finland

Figure 1 Grid Model

The grid model can be considered reasonably complete, in that we have brought the model up-to-date as of the end of 2023, but as lamented above, the behaviour of this model is severely compromised by the nature of the swing bus and the load modelling. The wind turbine models also need development, in terms of correctly modelling their short-term behaviour and the correct modelling of the Phase Lock Loop blocks. Apparently this problem is challenging to other research groups as well! A wind turbine park model block is shown in Fig. 2 below.

John Millar, Floran Martin, Janne Seppänen, Aalto University, Marius Baranauskas and Ari Silde, VTT Research Centre of Finland

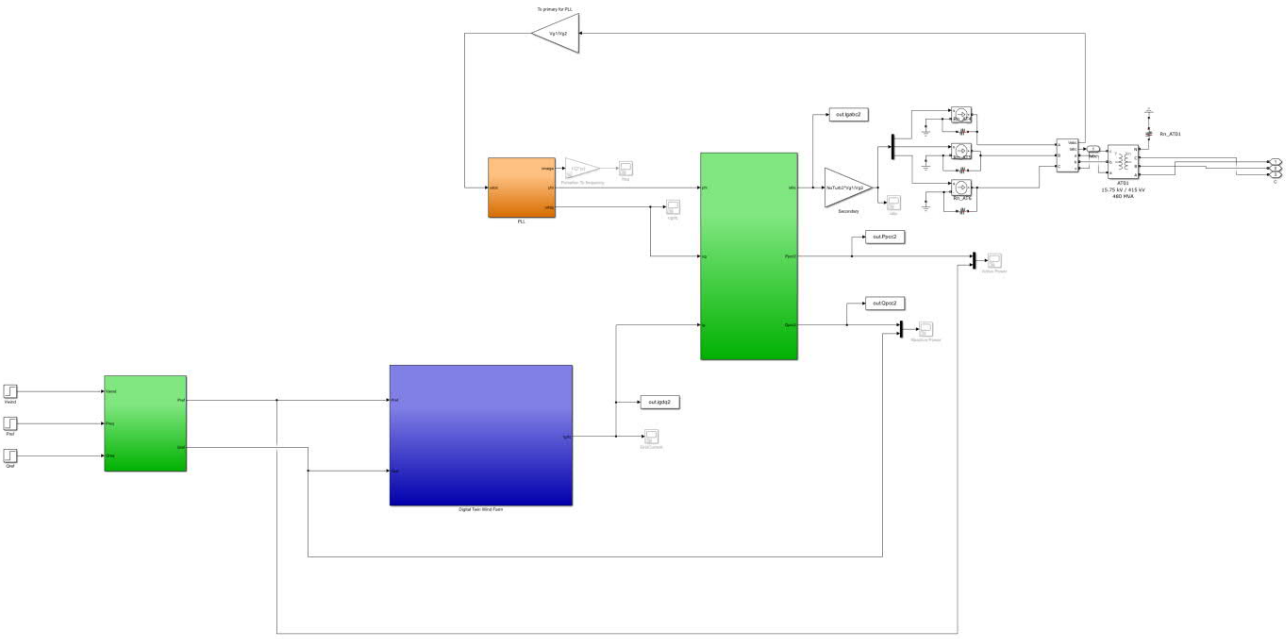

Figure 2 A wind turbine block developed for the grid model in T1.2. The model consists of numerous subsystems…

3 Results Grid-only simulations

Finally, a few grid-only simulation results will be shown, noting that the real results come from T2.3, the co-simulations with Loviisa's nuclear plant. The main drawback of the present transmission model is the modelling of the swing bus and the loads, which together *swallow up* the impact of inertia in the synchronous machines. In particular, the return to 50 Hz following the disturbance happens much quicker in simulation, e.g., Fig. 4, than in measured reality. At present we do not have permission to show measured data.

John Millar, Floran Martin, Janne Seppänen, Aalto University, Marius Baranauskas and Ari Silde, VTT Research Centre of Finland

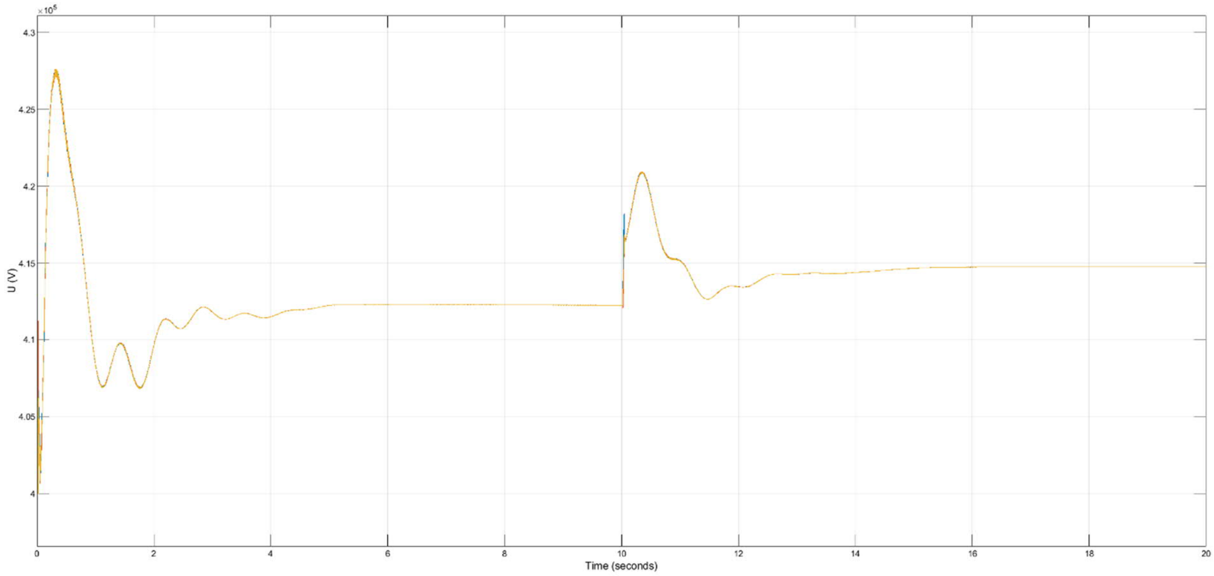

Figure 4 The voltage rise at Loviisa due to Estlink 2 tripping in Scenario 7 at 10s, low wind with winter loading

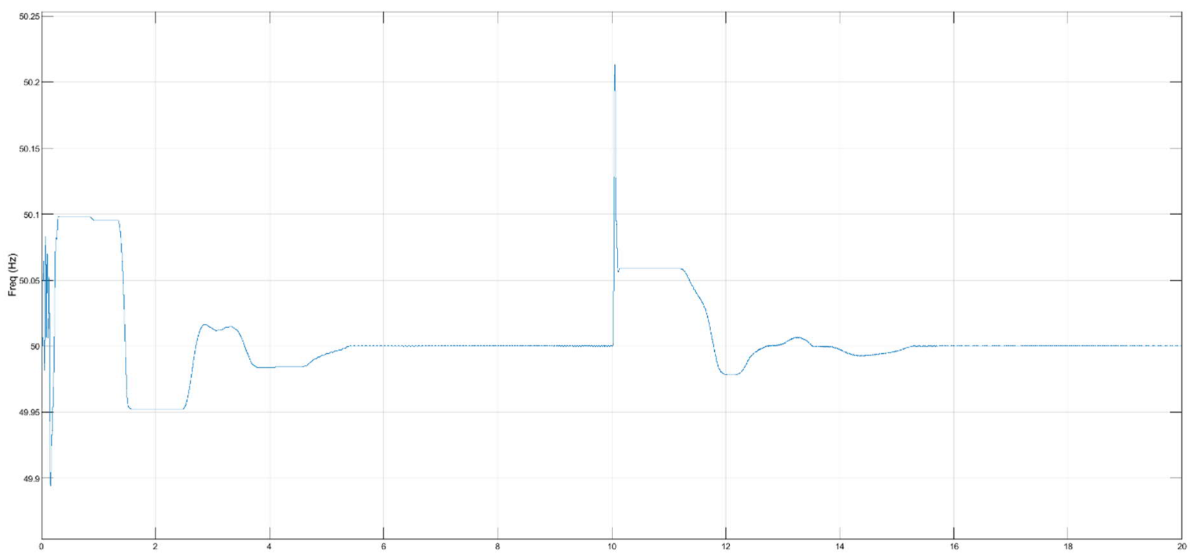

Figure 3 The way too rapid frequency response for Scenario 7

Aalto University
VTT

Postal address
P.O. Box 17800
FI-00076 AALTO

Visiting address
Maarintie 8
Espoo, Finland

www.aalto.fi/en
John.millar@aalto.fi

The results for Scenario 8, high wind during winter loading, show somewhat more high frequency oscillations, which may be expected from so much converter connected generation, but not so much as is shown in these simulations!

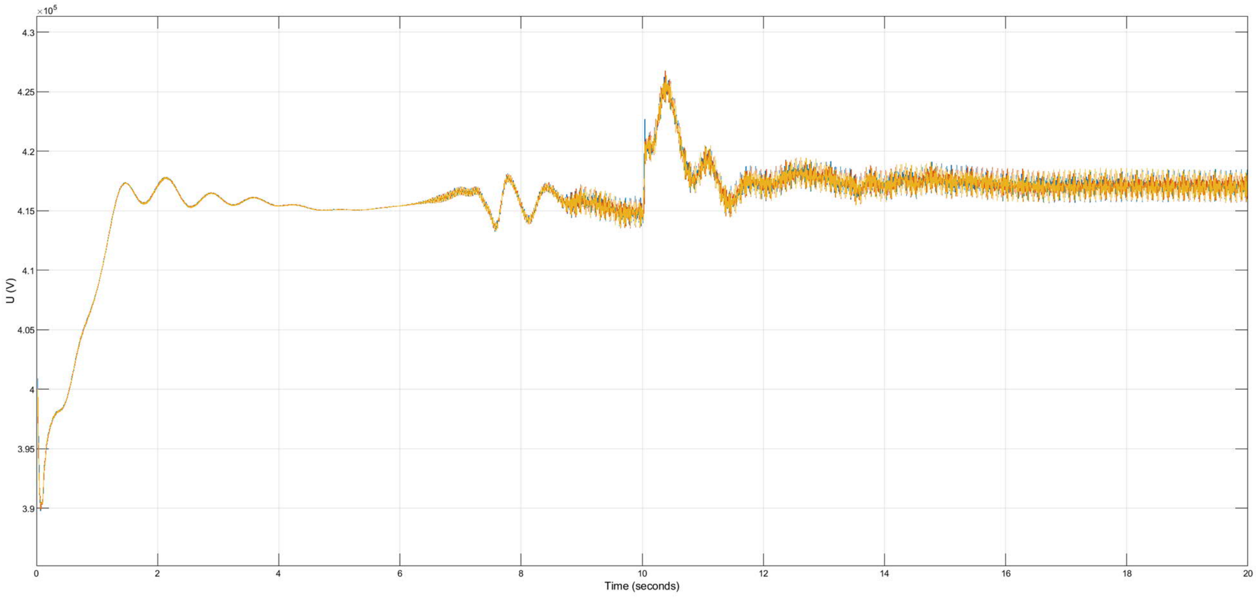

Figure 5 Scenario 8 voltage rise at Loviisa

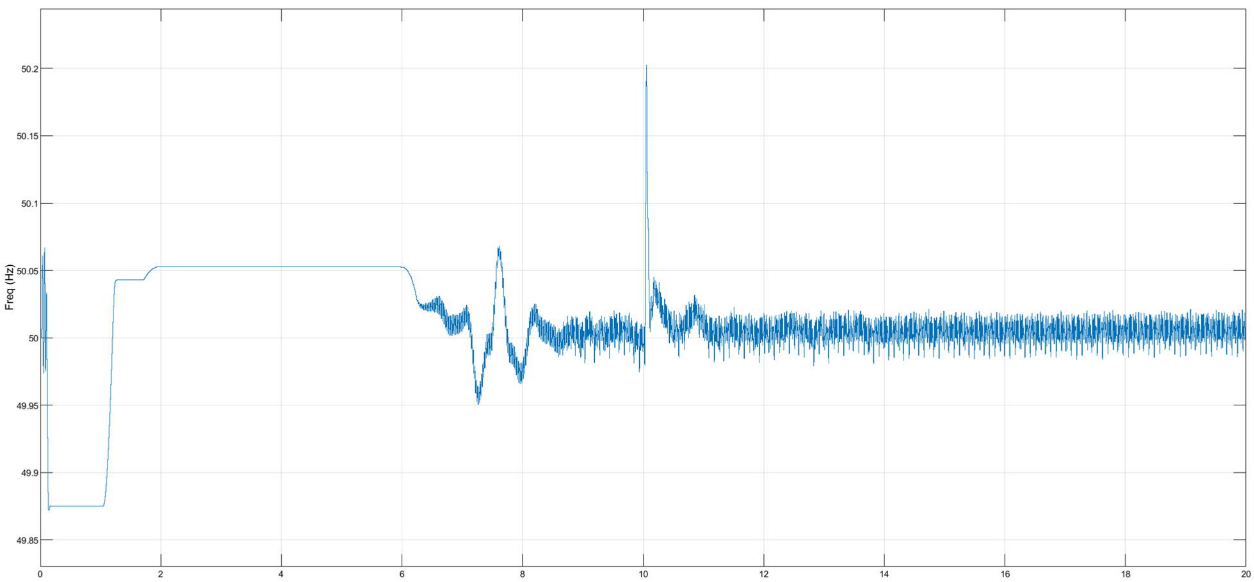

Figure 6 Scenario frequency response, with harmonics appearing when the wind turbines are connected in the simulation. The harmonics are overstated in simulation, but the time response of the power frequency deviation is understated by more than an order of magnitude…

Aalto University
VTT

Postal address
P.O. Box 17800
FI-00076 AALTO

Visiting address
Maarintie 8
Espoo, Finland

www.aalto.fi/en
John.millar@aalto.fi

4 Discussion

There has been significant work carried out on the transmission grid model, but not all of it is ready for implementation. We are ahead of schedule in HVDC connection modelling (not yet implemented) and wind park modelling (implemented, but still requiring development).

Other developments include synchronous machine swing bus(es) (not implemented due to stability issues), power system stabilizer development (we have a model that is closer to what is used in Finland (but we are still using a multi-band Power System Stabilizer because it is easier to parameterise), addition of more CHP generation in the south of Finland to better represent present reality, some new 400 kV connections, addition of numerous connection points and series compensators. As indicated, we have had to back-track somewhat to maintain stability in the model, and it is the swing bus and load modelling that we must primarily solve in 2024, to equip the model to better cope with post-contingency transients.

Aalto University
VTT

Postal address
P.O. Box 17800
FI-00076 AALTO

Visiting address
Maarintie 8
Espoo, Finland

www.aalto.fi/en
John.millar@aalto.fi