CONTROL DEVELOPMENT AND MODELLING FOR FLEXIBLE DC GRIDS IN MODELICA

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Introduction

Electrical power consumption is ever increasing and production by local renewable sources is also increasing. In practice, this means that power distribution networks needs to be able to handle more power flux scenarios than before. Such flexible power grids, "Smart grids", have several units coupled together and need to be intelligently controlled to keep desired voltage level. The control is performed by converters, both AC and DC, which are fast enough to provide controllability.

Converter Control

A flexible converter model has been implemented supporting the following control algorithms: active front end (AFE), power controlled AC/DC and droop controlled AC/DC.

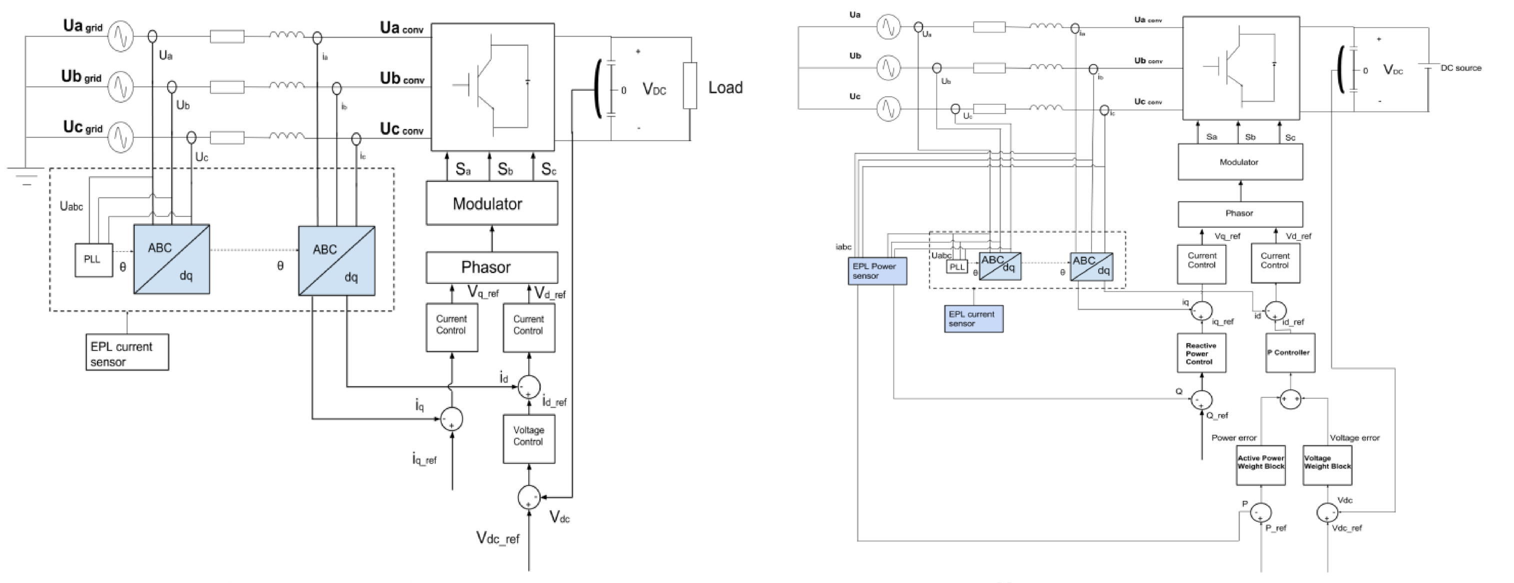

Figure 1: Left: Active front end, Right: Droop controlled.

Experimental Setups

Multi-terminal HVDC scenario

Three multi-controlled converters were connected in parallel together with an AFE for controlling the DC voltage of the utility grid, see Figure 2. The converters were set to power control and the generators and utility grid were represented by AC sources at 150-400MW. Square and sinusoidal waves were used for power references of the converters.

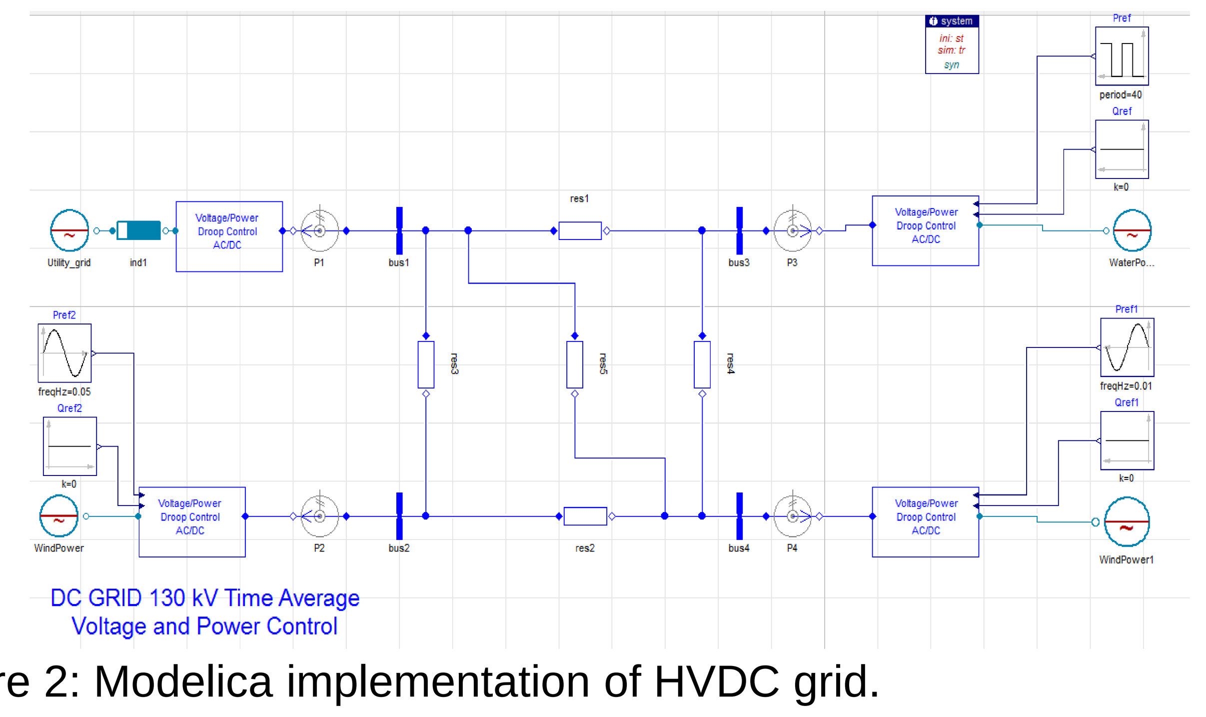

Figure 2: Modelica implementation of HVDC grid.

Household with local energy production

Mimics a household with local power production; two wind turbines (4kW) and a solar power plant (0-2kW) were connected to a DC grid as well as a model of a "smart" house. See Figure 3 for Modelica implementation.

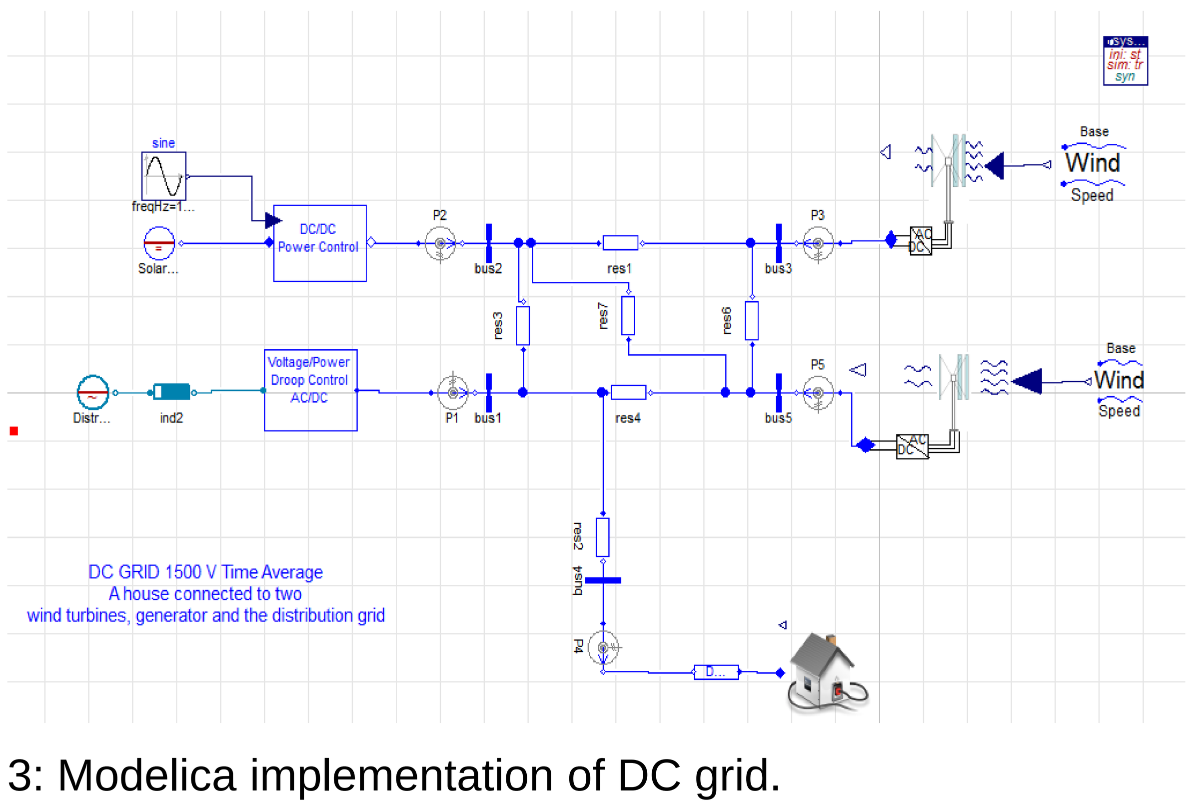

Figure 3: Modelica implementation of DC grid.

Results

Multi-terminal HVDC scenario

Large reference changes in the supplied power from the hydro power plant yielded realistic effects on the power generated by wind power plants, see Figure 4. Sudden changes in power will affect the current flowing through the circuit. Recovery controlled by the converters were swift with minor under/overshoots. No noticeable changes were made in the voltage between grid and utility net.

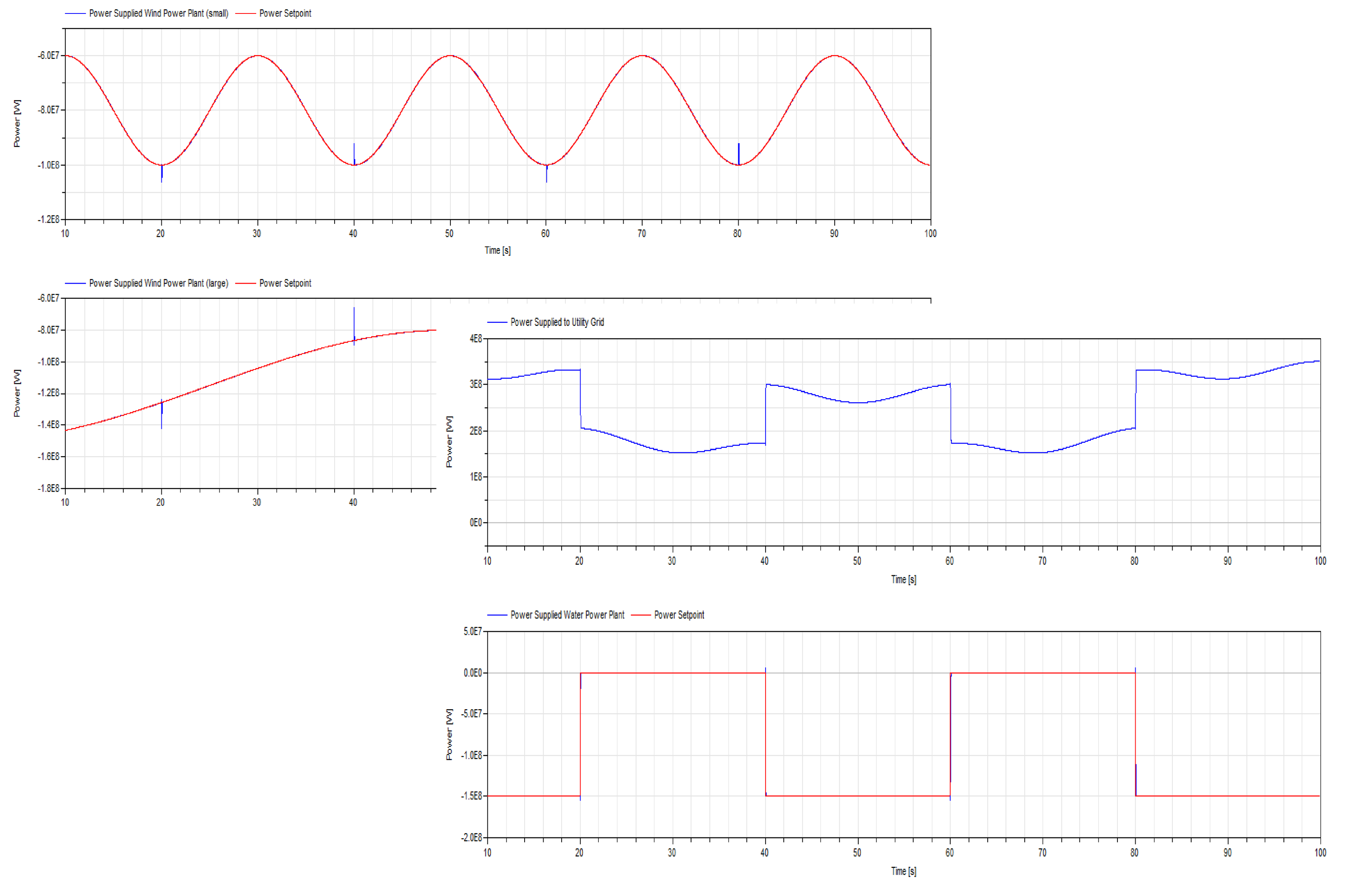

Figure 4: Left: Power generated by wind power plants. Right: Power generated (top) and supplied (bottom) by hydro power plants.

Household with local energy production

Quick load increase yields voltage drop with fast recovery by the voltage controller, see Figure 5. Main parts of the consumed load was provided by wind and solar power plants, while excess power was fed to AC distribution grid, also seen in Figure 5.

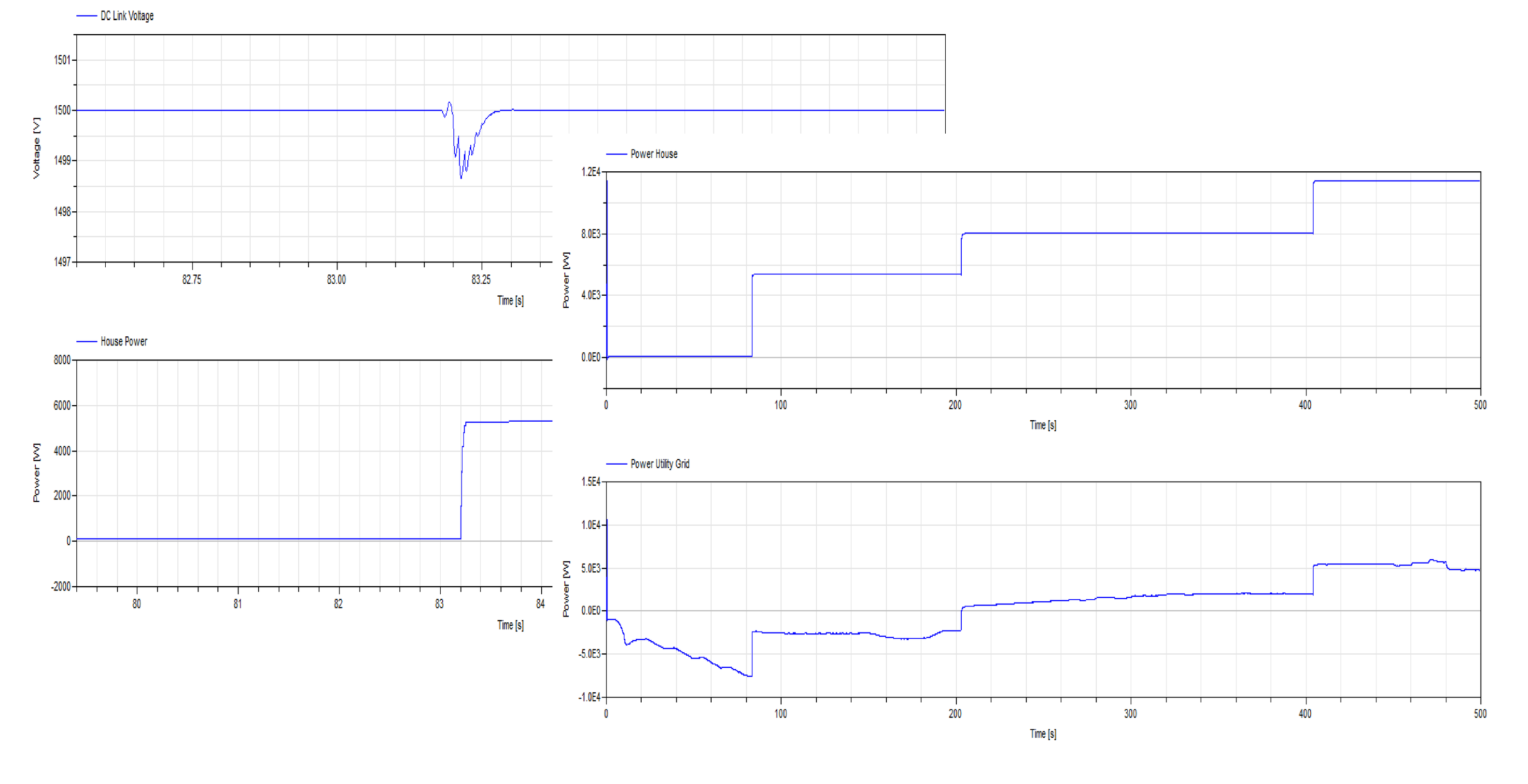

Figure 5: Left: Voltage (top) of the DC grid reacting on sudden change in power consumption (bottom). Right: Power consumed by load (top) and power supplied to/consumed from AC distribution grid (bottom).

Conclusion

Implemented converters and control strategies maintains grid voltage and power flow as expected. This shows that the models can be interconnected and work in a stressed environment. It also shows that an arbitrary grid can be constructed and simulated for system and grid analysis.

The models have been connected with external library models, such as wind power models and energy consumers with local generation, showing compatibility with other libraries. This gives opportunity to interface with other libraries for assembling e.g., vessel grids, charging stations for electrical vehicles and wind power farm grids.

The presented models can be improved by including switching and thermal losses not currently accounted for.