Stability studies using EMT and RMS models of VSC converters

Deliverable 3.5: Feasible implementable approaches to modelling dynamic converter interactions with the large-scale AC system and wind farms

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Introduction

- **Traditional power systems** → dynamic behavior dictated mainly by synchronous machines;
- **Modern power systems** → increased amount of power electronic devices due to renewable energy and HVDC
  - — Converter control loops with large bandwidths → fast dynamics;
  - — Decrease the total system inertia and the power system strength.
- **Consequences**:
  - — Subsynchronous oscillations;
  - — High-frequency resonances between converters and the grid;
  - — Control interaction between converters.

Simulation of converter interactions

- Two approaches are typically used: Electromagnetic Transient Programs (EMT) and transient stability programs (RMS).

	Electromagnetic Transient Programs	Transient Stability Programs
Solution method	— Instantaneous values of variables are calculated by solving the differential equations	— Variables are represented by phasors and sometimes only solved for positive sequence values
Assumptions	— No implicit assumptions	— Variables do not deviate significantly from nominal frequency
Frequency range of accuracy	— Wide frequency range, depending on choice of models	— Only accurate around nominal frequency
Simulation time step	— Microseconds	— Few milliseconds

Modelling converter interactions

- In the past there was a clear timescale separation between fast and slow system dynamics → converters blurred this distinction
- It is more challenging to choose when to use each modelling approach and associated simulation tool.

Which modelling approach to use in this scenario?

Using EMT approach

— Modeling requires detailed data of components;

— Large computational effort (simulations might be slow).

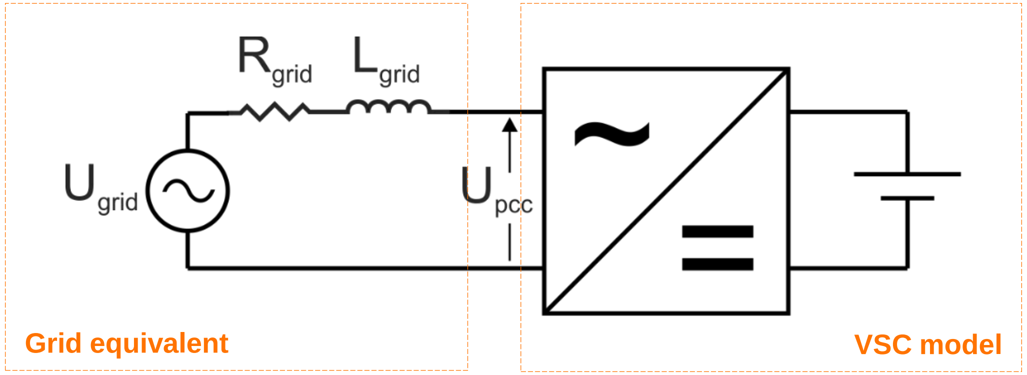
Using RMS approach

— Assumptions used in quasi-stationary phasor modeling pose restrictions on the dynamics that can be observed from the converters.

Growing need to understand the impact of modeling detail and assumptions.

Example: VSC stability study

- **Objective**: to understand how a VSC converter might interact with the grid and what modelling approach should be used.
- **Methodology**:
  - Analyze the influence of system strength on VSC stability.
  - Determine whether RMS models can be used.
- **VSC model**: averaged VSC converter with current control, PLL and active and reactive power controls.

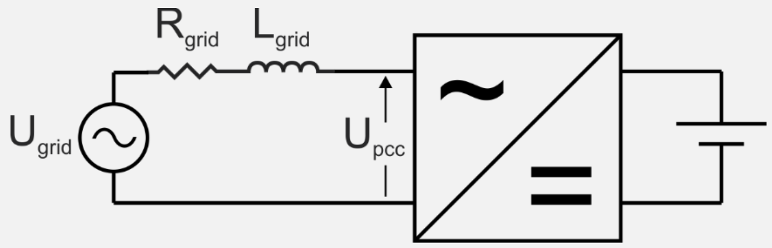


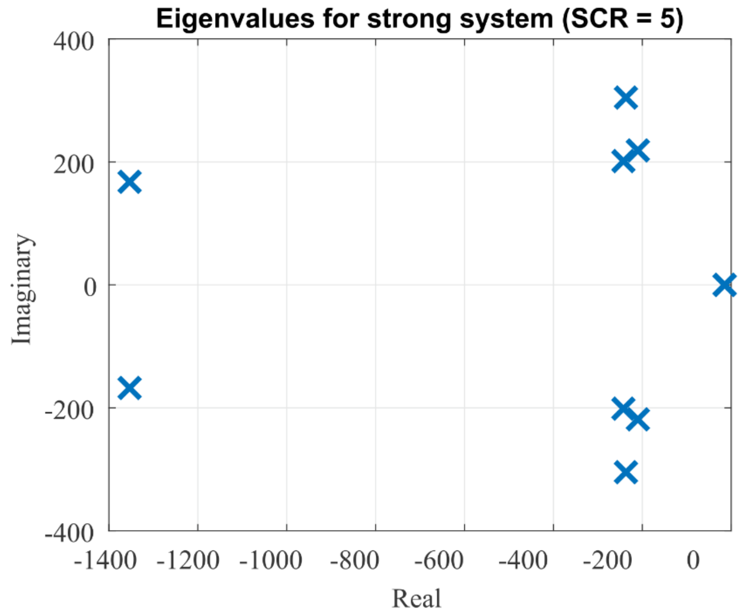
Example: VSC stability study

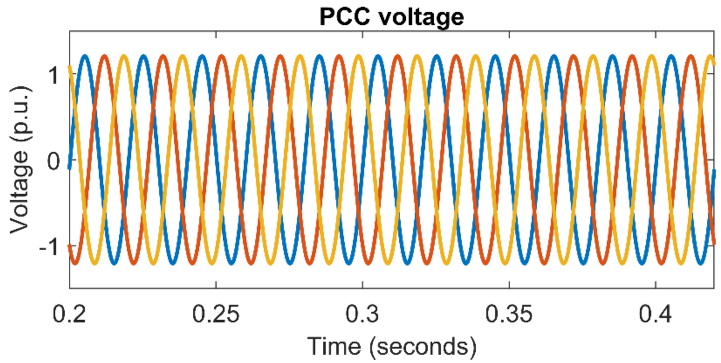
EMT modelling: influence of grid strength

- When the grid is strong (SCR = 5) no instability is observed;
- All eigenvalues have negative real parts;
- Voltage is stable following a small power setpoint change.

EMT study case: strong grid





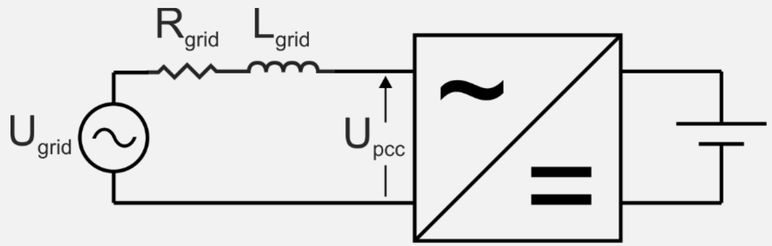


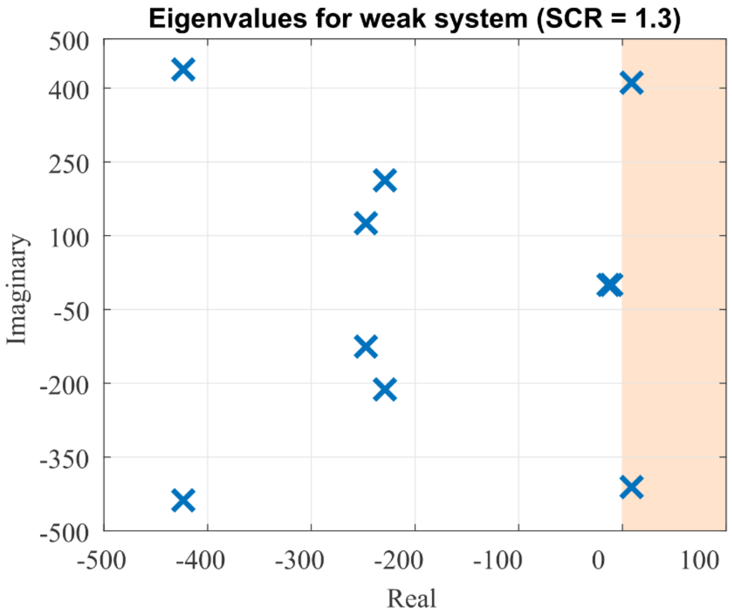
Example: VSC stability study

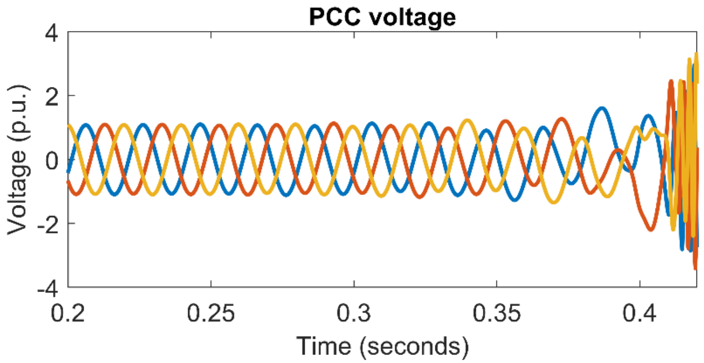
EMT modelling: influence of grid strength

- When the grid is weak (SCR = 1.3) the VSC becomes unstable;
- Two unstable eigenvalues: $\pm 8.8 + j411.1$;
- Voltage indicates instability after small power setpoint change.

EMT study case: weak grid



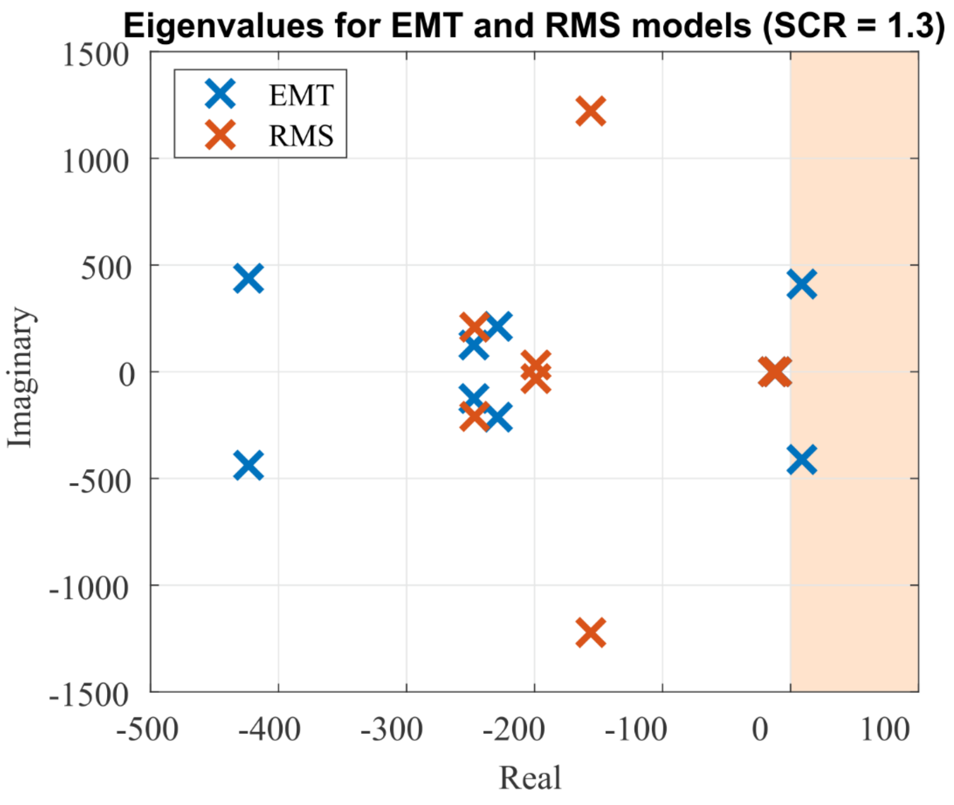




Example: VSC stability study

Performance of RMS models in weak grid

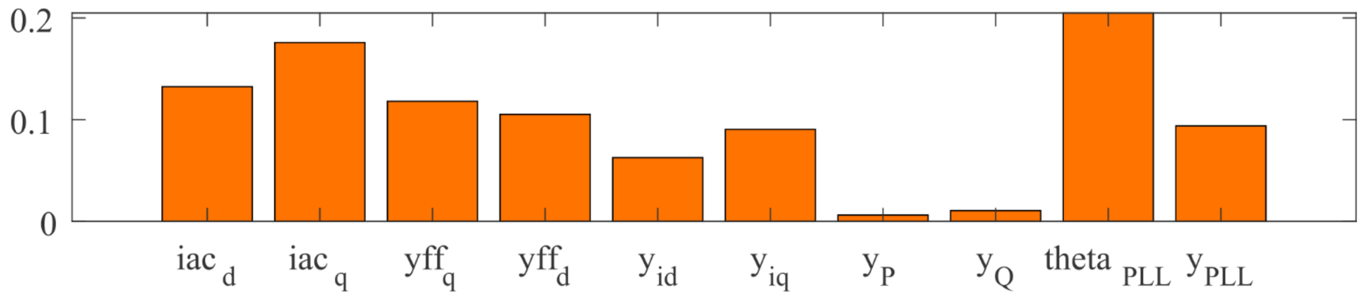
- Both grid and VSC are modelled in RMS and compared with the EMT case;
- For a weak grid (SCR = 1.3) the RMS model is not capable of showing the instability observed in EMT;
- EMT has two unstable eigenvalues $\pm 8.8 + j411.1$, but RMS does not;



Example: VSC stability study

Analysis of results

- The state variables corresponding to the AC currents i_{AC}^{d} and i_{AC}^{q} have high contribution to the unstable eigenvalues observed in EMT;
- In the RMS model, these state variables (i_{AC}^{d} and i_{AC}^{q}) are not present because of the phasor assumptions;
- This explains the observed difference between EMT and RMS stability assessment.



Conclusions

- The grid strength has large impact on the stability of a grid-connected VSC;
- Stability analysis in EMT showed that the AC currents and PLL state variables contribute the most to the unstable eigenvalues in weak conditions. The current dynamics cannot be represented in RMS studies and PLL dynamics are often left out.
- Initial study showed that the RMS model was not capable of representing the stability limits under weak conditions. This indicates EMT models should be used in this case.

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