Project memo AN 03.12.103

Average model of PWM converter

Objective

Implement and test an averaging model of a three-phase pulse-width modulated (PWM) converter.

The purpose of the model is less complexity and faster time domain simulation studies of grid connected converters, while still maintaining sufficient converter dynamic accuracy.

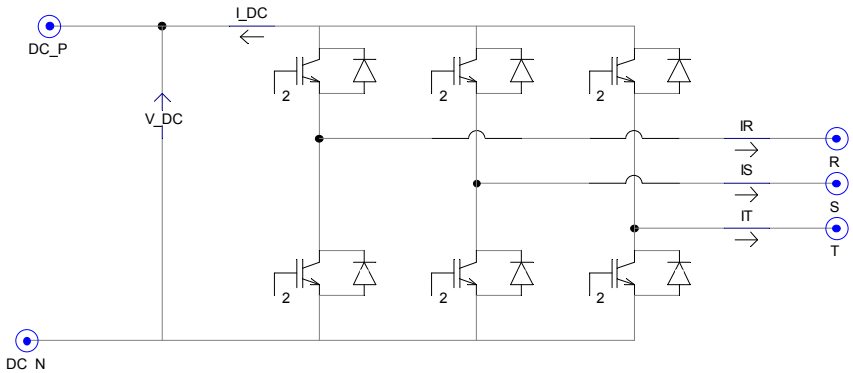
(converter interaction phenomena, stability,

short circuit analysis)

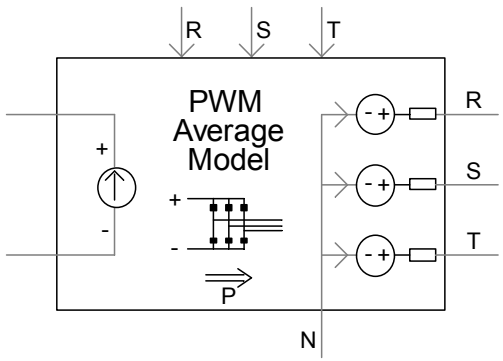
Description of implemented model

- The model has the same average V-I terminal relationship on AC and DC side as a full switched model (averaged over one switching period).
- Simulation time steps larger than the switching period can be used since the switches are not modelled.
- The control circuit is modelled in the same way as if a full switched model were used except that modelling of gate-pulse generation is not needed.
- Over-modulation, saturation effects and other non-linearity's are also modelled correctly
- The model is not suited for analysis were consequences of switching frequency ripple phenomena are focused.

Full switched model of 3-phase PWM-converter



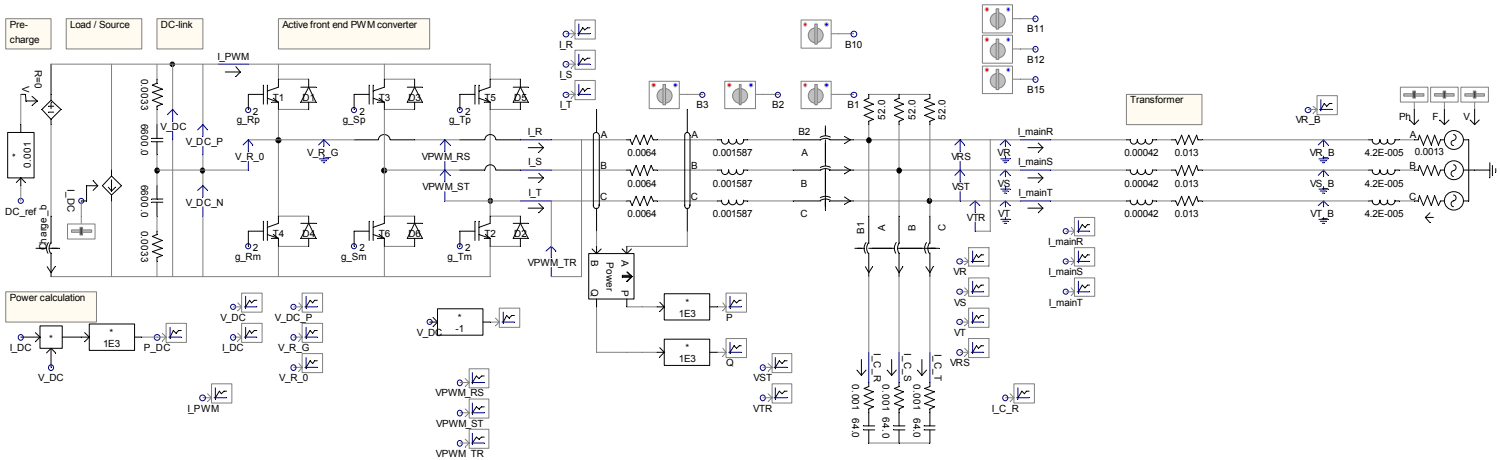
Implemented averaging model of the same converter



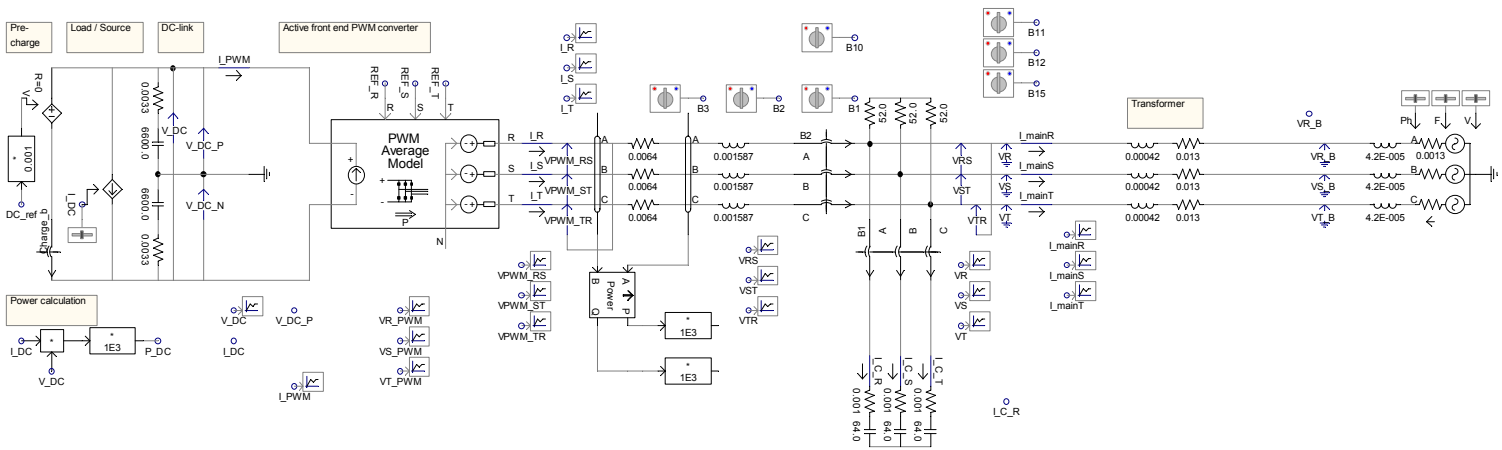
Example of use

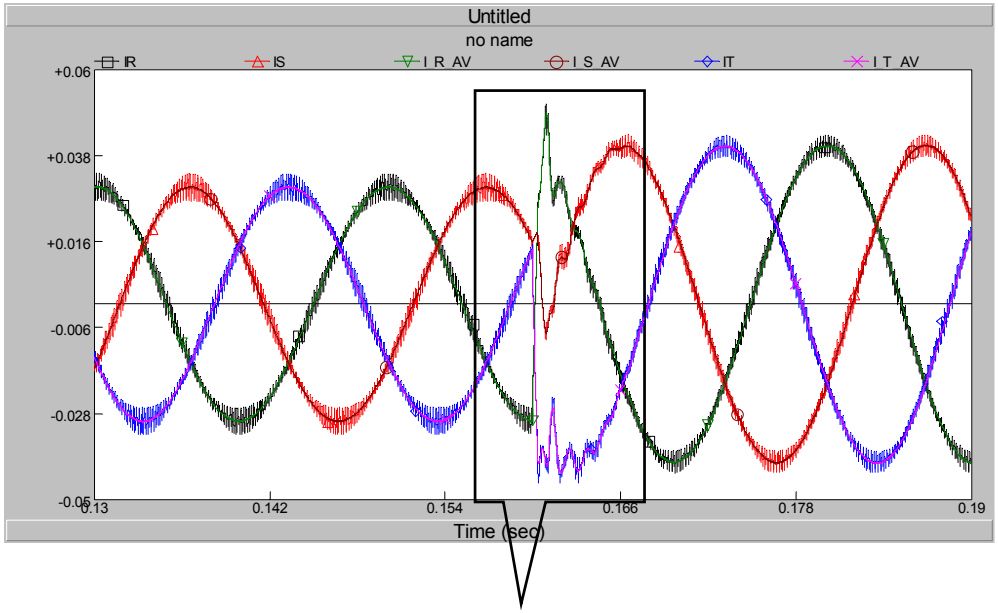
- The case used to illustrate the model performance is a step reversal of the reactive power reference to a grid connected PWM converter.
- The converter is connected to a DC-link capacitor on the DC-side.
- A LC-filter is included on the AC-side
- No load or source is connected to the DC-side.
- The converter is controlled such that the DC-link voltage is kept constant
- Simulation results using both switched model and average model are shown on the following slides

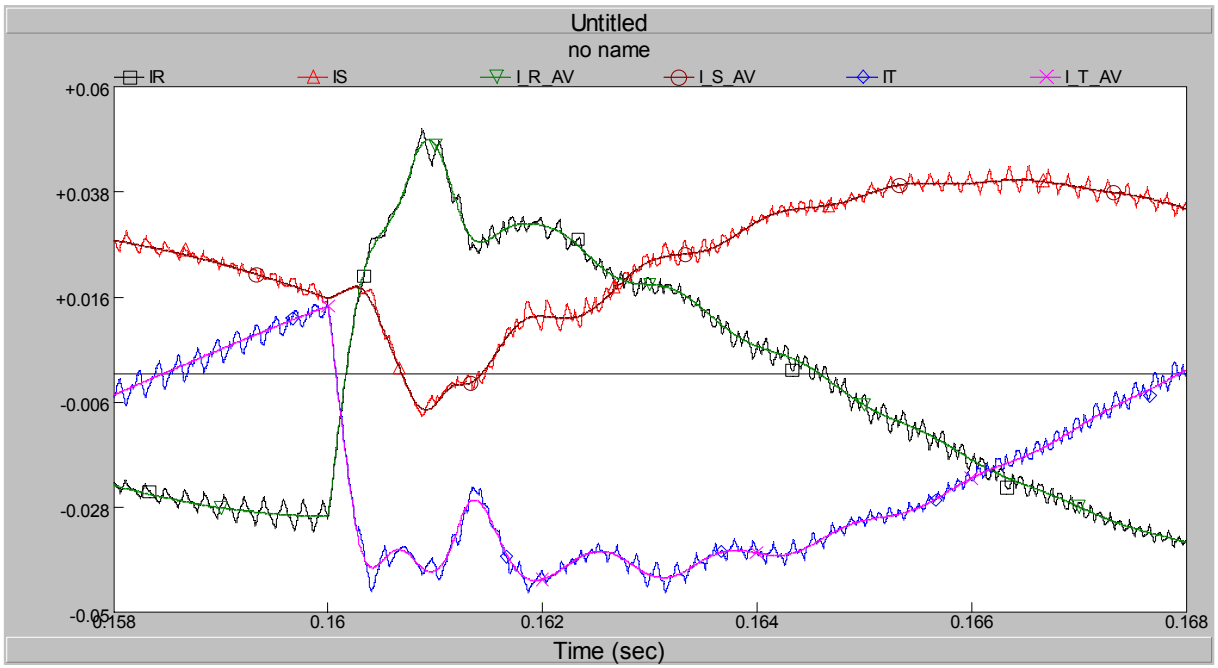
Full switched model (control circuit not shown)



Averaging model (control circuit not shown)

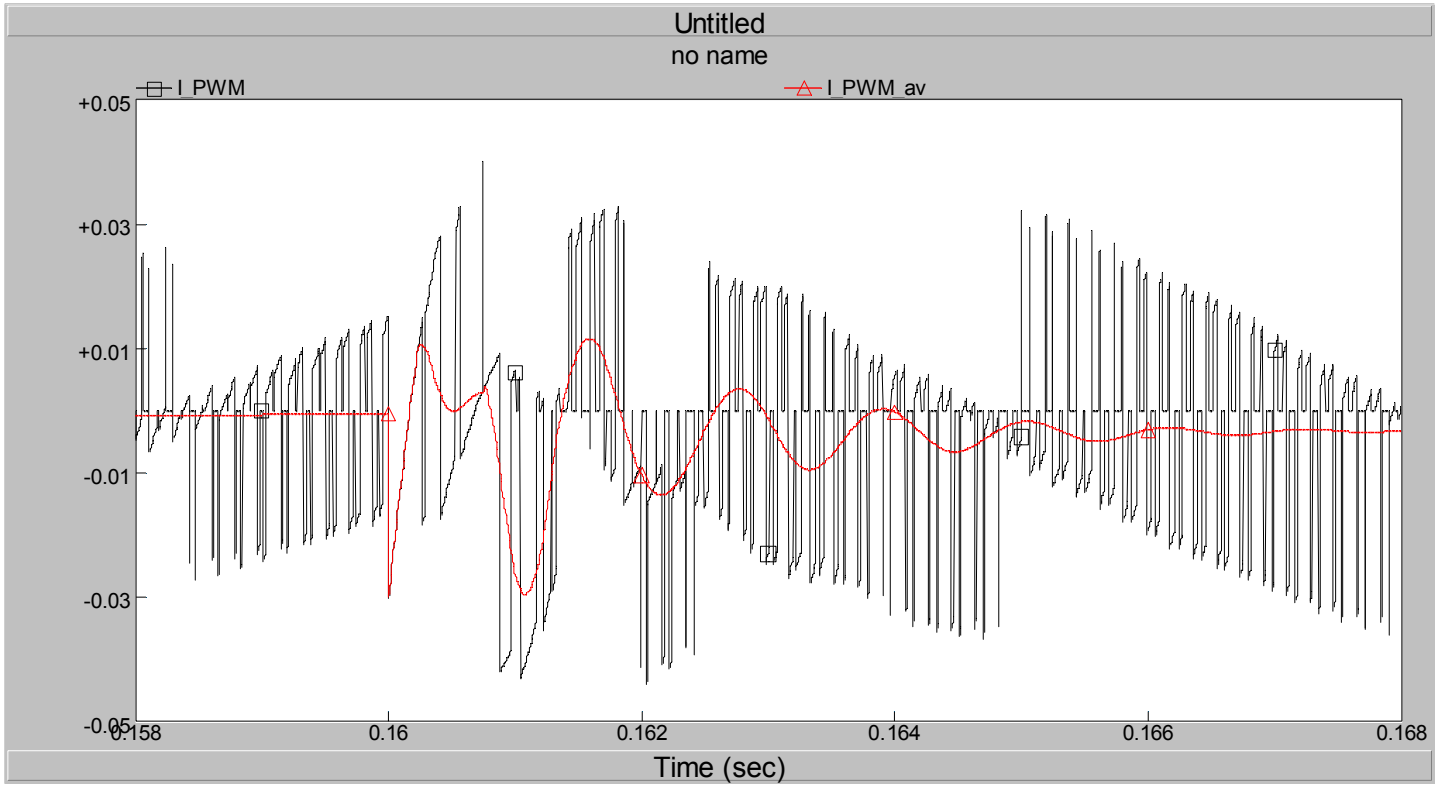






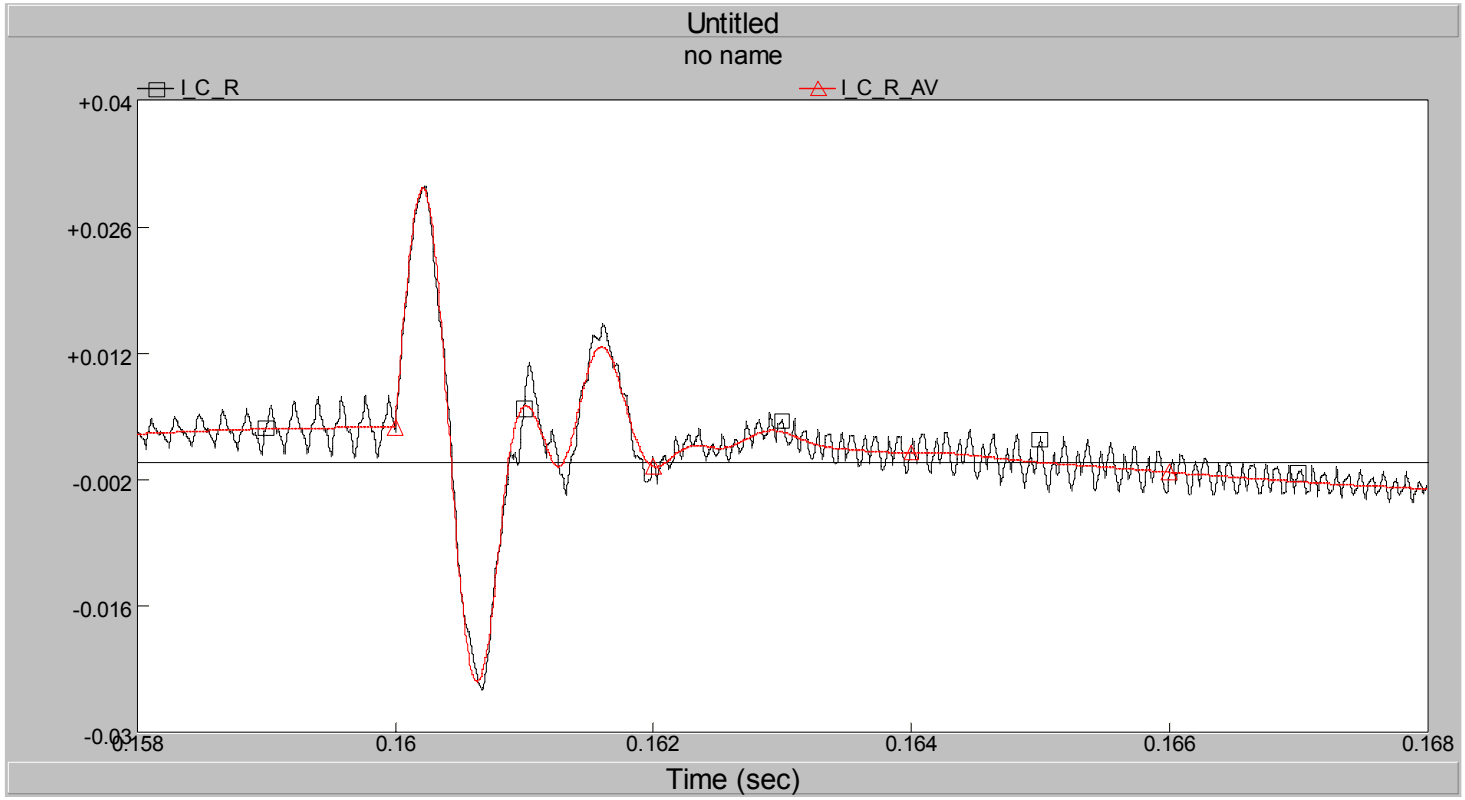
Filter inductor currents (kA) for switched model and for average model just before and after the reactive power reversal

(switched model and average model)



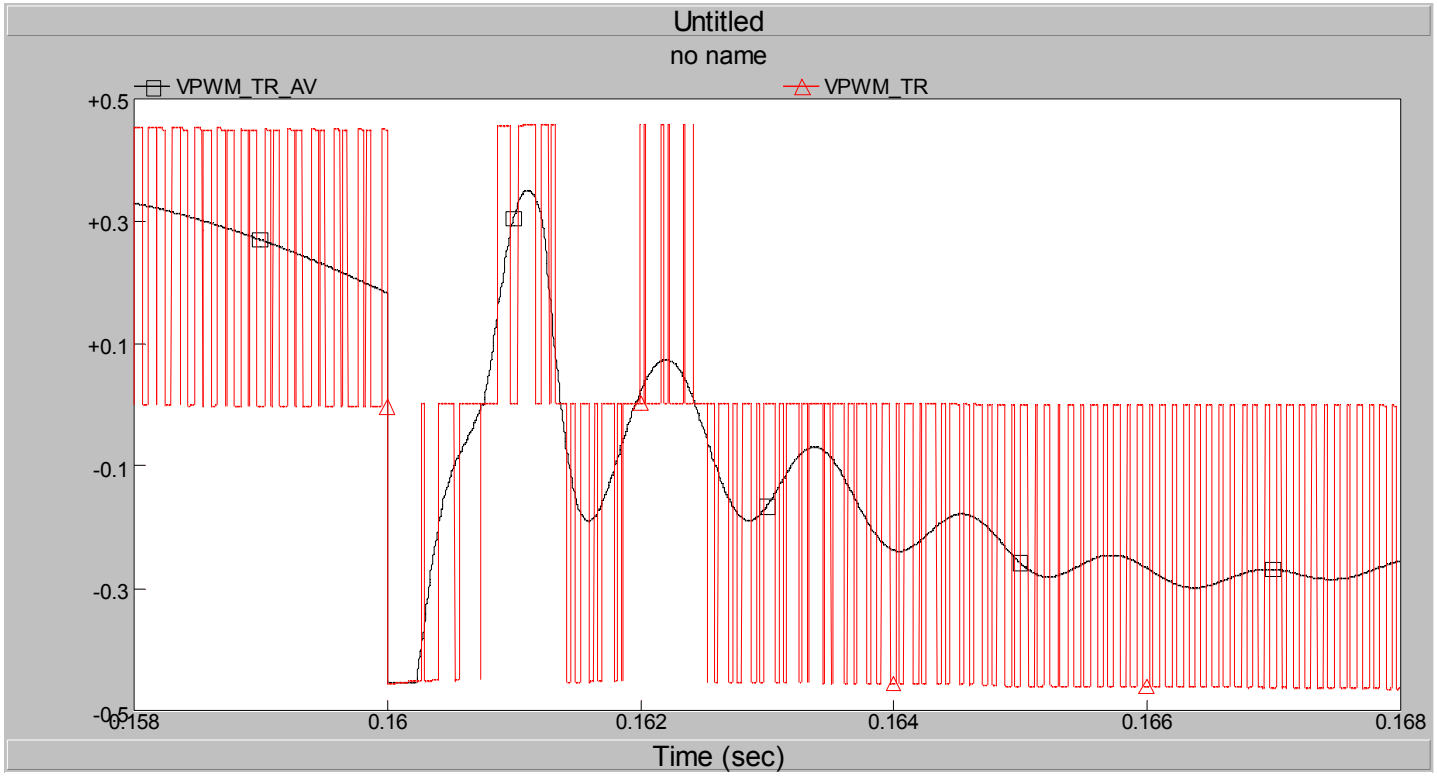
Current (kA) in DC-link capacitor just before and after the reactive power reversal

(switched model and average model)



Current (kA) in phase R filter capacitor just before and after the reactive power reversal

(switched model and average model)



Converter TR line output voltage (kV) just before and after the reactive power reversal

(switched model and average model)

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AN NO.	CLASSIFICATION	REVIEWED BY	
AN 03.12.103		Tormod Kleppa	
ELECTRONIC FILE CODE		AUTHOR(S)	DATE
		Olve Mo	2003-12-04
PROJECT NO.			NO. OF PAGES
12X127.02		olve.mo@sintef.no	17
DIVISION		LOCATION	LOCAL FAX
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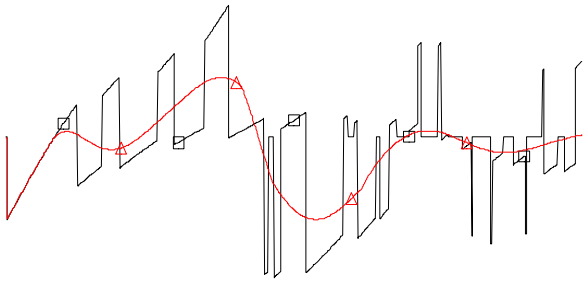
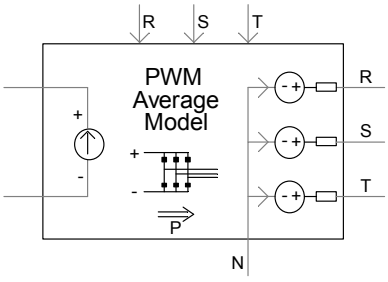
This memo present results of the Strategic Institute Programme (SIP) “Power electronics and energy storage technologies for cost- and energy efficient power systems” funded by The Research Council of Norway.





Described is a new model developed for the PSCAD/EMTDC simulation program. The new model is an average model of a three phase, two-level, PWM converter. The model performs as a PWM-converter, except that switching frequency phenomena’s are averaged over the switching period. Voltages and currents on both AC- and DC-side is therefore smooth and without switching frequency ripple.

The typical application of such a model is in analysis were several converters are connected to an AC-grid. The model makes it possible to run the simulation with much larger time steps. The consequence is that the simulation can be run much faster and/or that larger time-spans can be simulated.

The phases can be controlled individually. The models also perform correct in over-modulation. It is possible to use it to model PI-current control, tolerance band control and other control schemes.

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