Fault current contribution from DG

-Synchronous generator

-Asynchronous generator

-PV inverter (and other converters with low power rating)

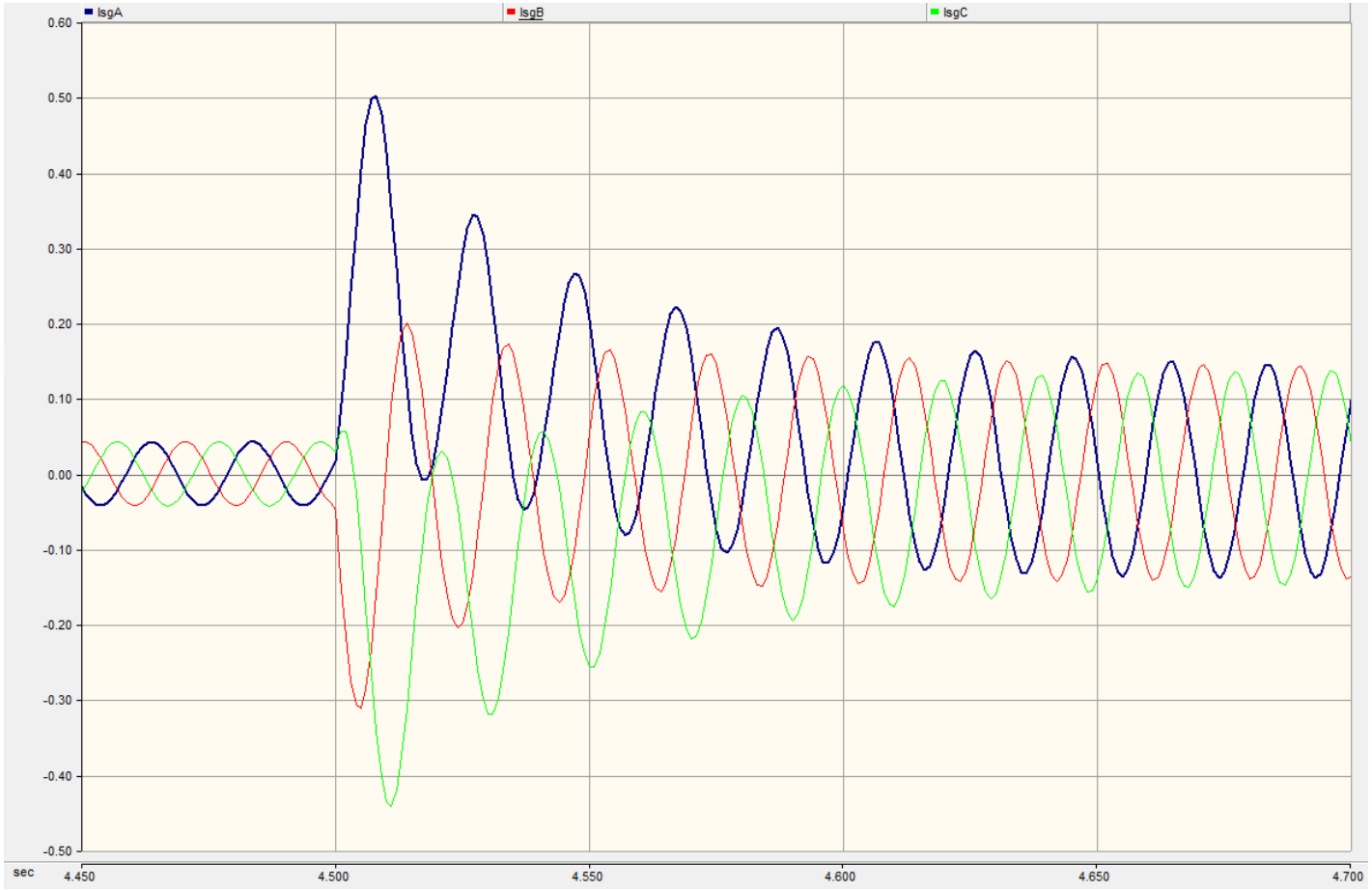
Nordic Workshop on Power System Protection and Control

Trondheim-Norway May 25, 2016

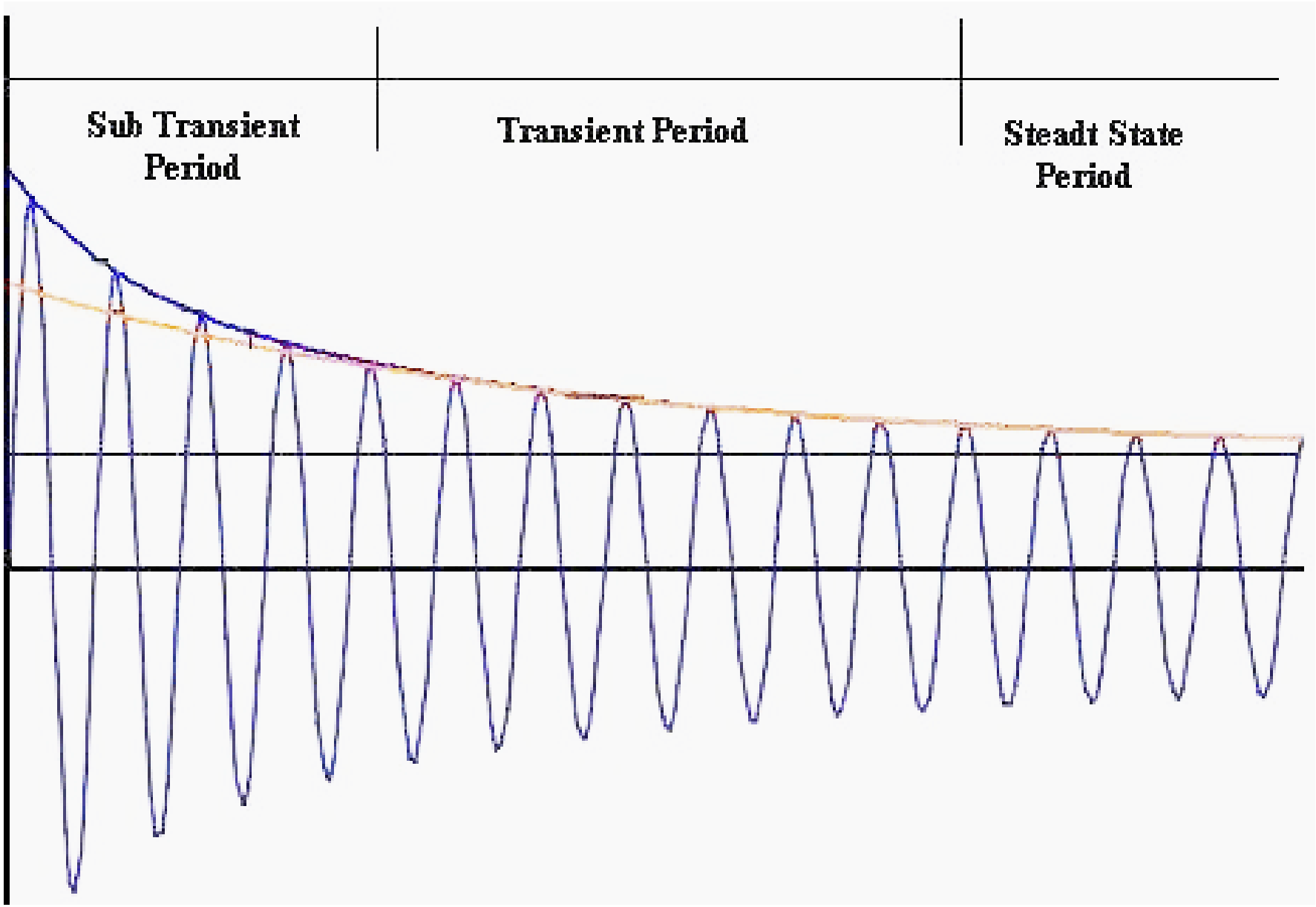
Tor Inge Reigstad, SINTEF Energi

Synchronous generator short circuit current contribution

- Peak ac-component: ~6 times rated
- Max dc-component: same as peak ac
- Goes to steady-state value, depending on synchronous reactance and AVR



Synchronous generator short circuit current contribution

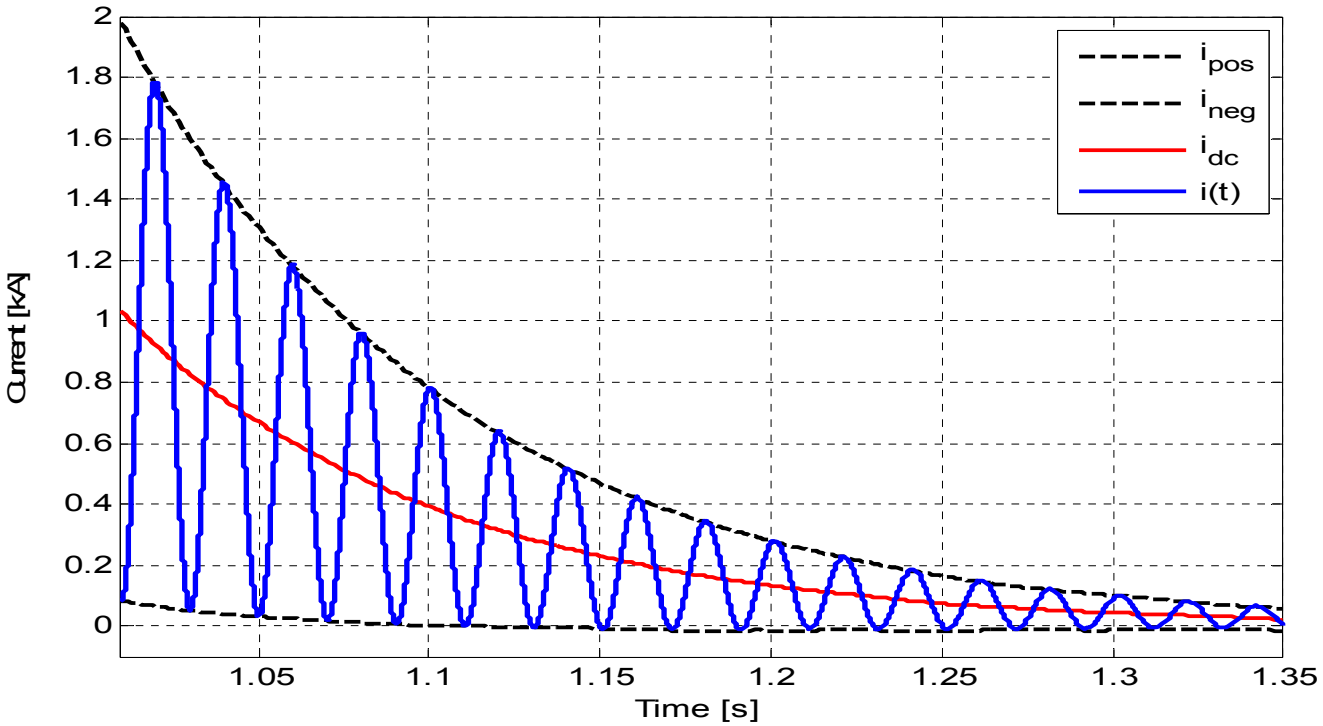


Synchronous generator short circuit current contribution

Reactance	Description	Symbol	Range per-unit	Period
Sub-transient reactance	Determines maximum instantaneous current and current at time Molded Case Circuit Breaker usually open	Xd″	0.09 – 0.17	0 – 6 Cycles
Transient Reactance	Determines current at short time delay of circuit breakers	Xd′	0.13 – 0.20	6 cycles to 5 sec.
Synchronous reactance	Determine steady state current together with AVR	Xd	1.7 – 3.3	After 5 sec.
Zero sequence reactance	A factor in L-N short circuit current	X0	0.06 – 0.09	
Negative sequence reactance	A factor in single-phase short circuit current	X2	0.10 – 0.22	

Asynchronous generator short circuit current contribution

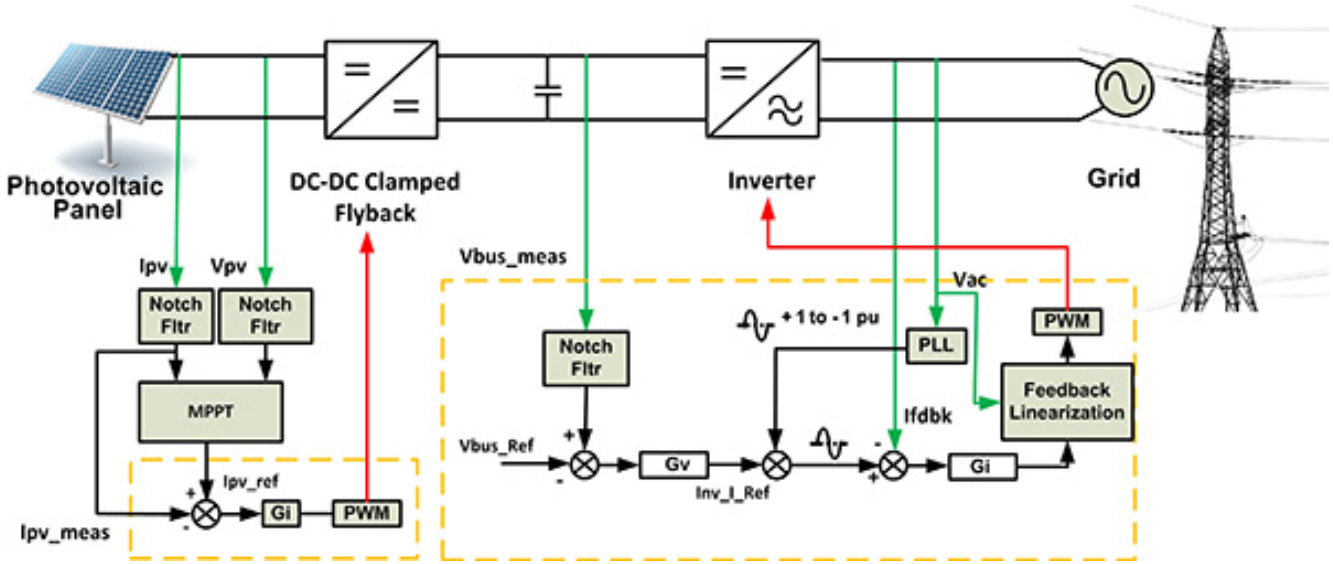
- peak ac-component: ~6 times rated
- max dc-component: same as peak ac
- decays to zero (no AVR)



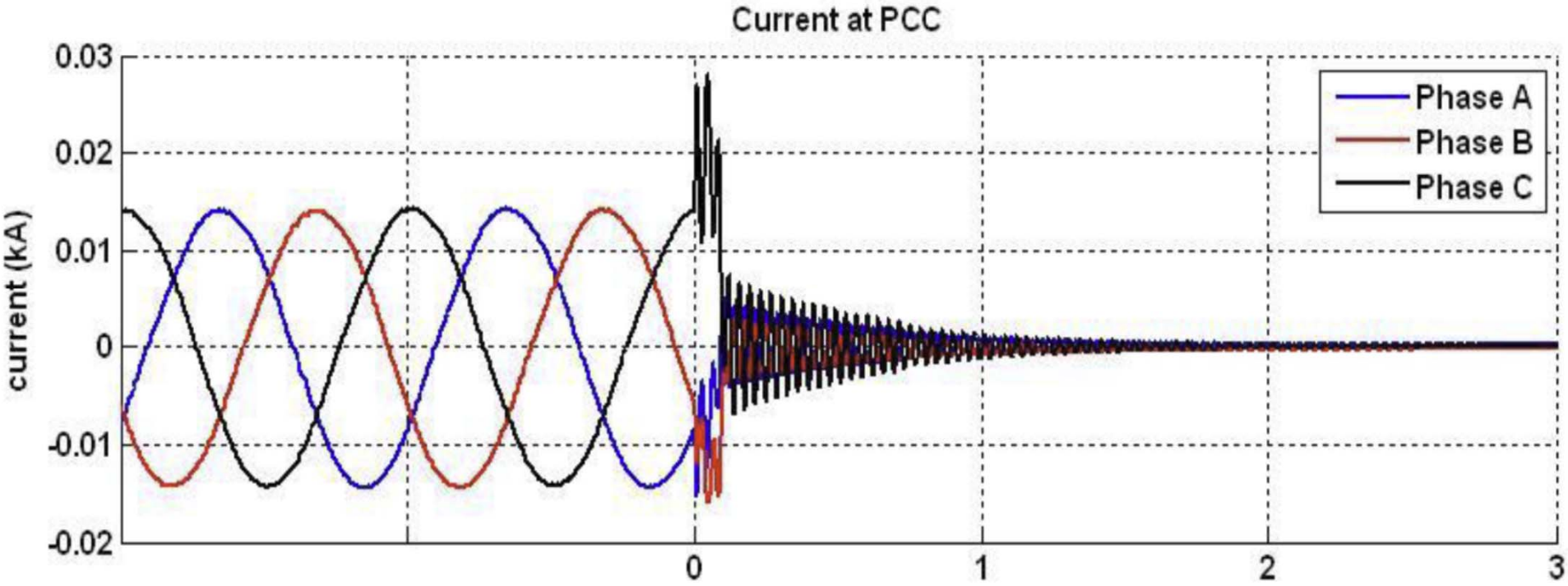
PV inverter short circuit current contribution

- A PV inverter's current contribution during a fault is
  - not zero
  - varies by design
- The output current is limited by the current-carrying capability of the power electronic switches.

- Quanta Technology has investigated the behaviors of 12 different PV inverters during faults. The PV inverters are grouped into two categories:
  - Model 1
  - Generic model



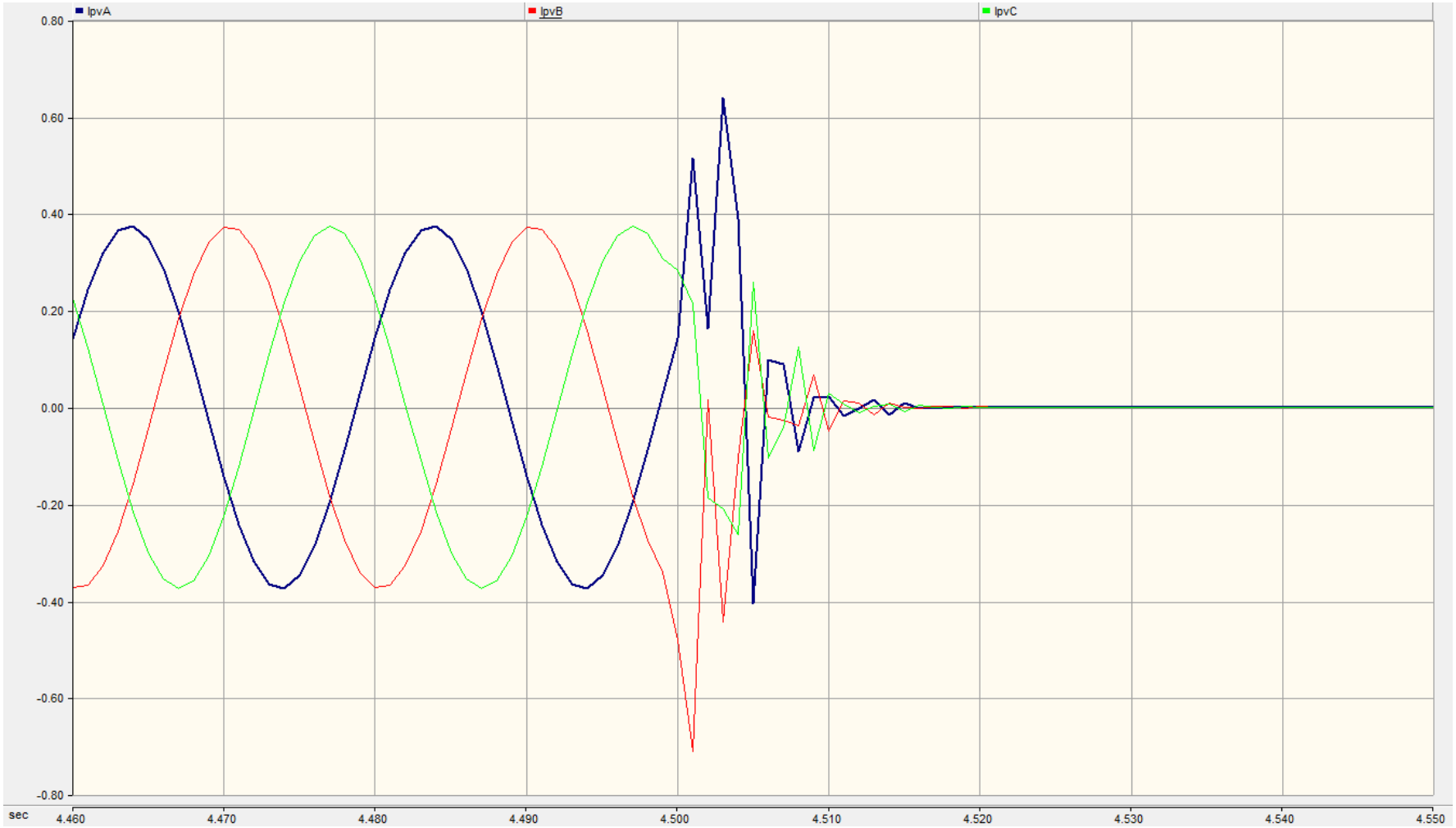
PV inverter: Model 1



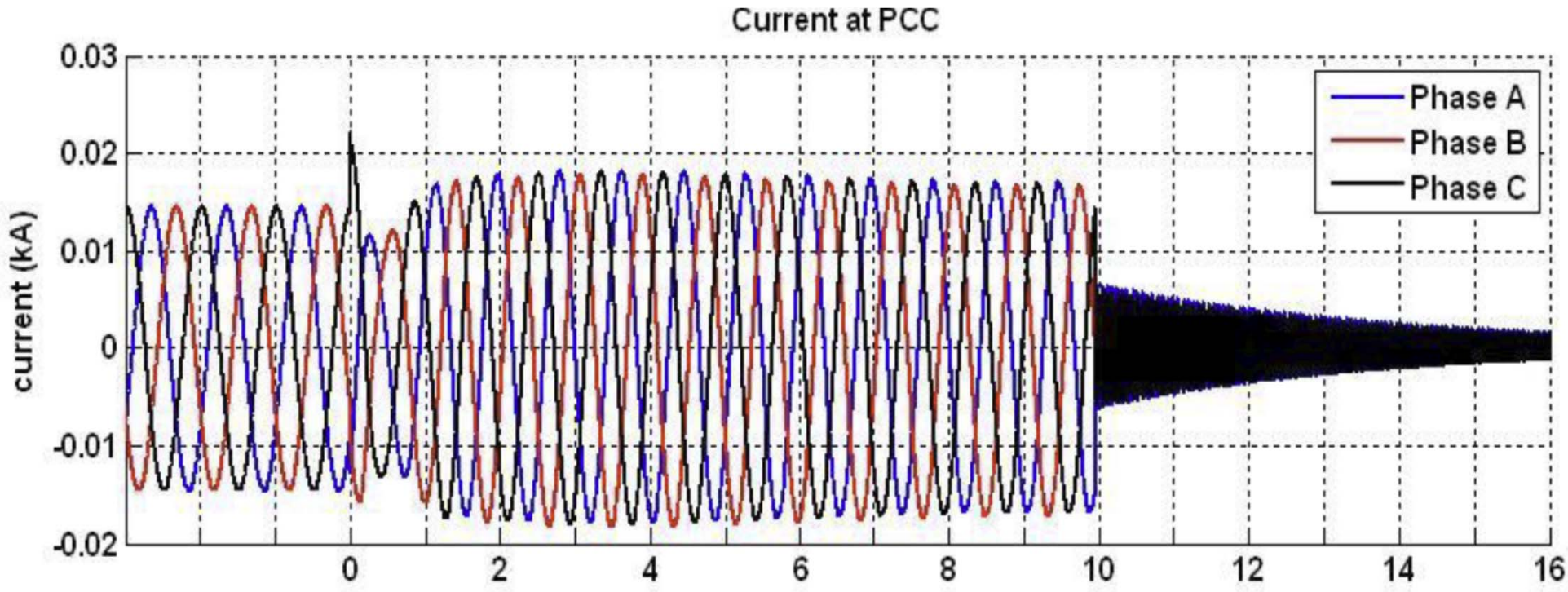
Model 1:

- Fast disconnection (less than one cycle).
- If the PCC voltage drops below 50%, the inverter current is immediately interrupted.

PV inverter: Model 1



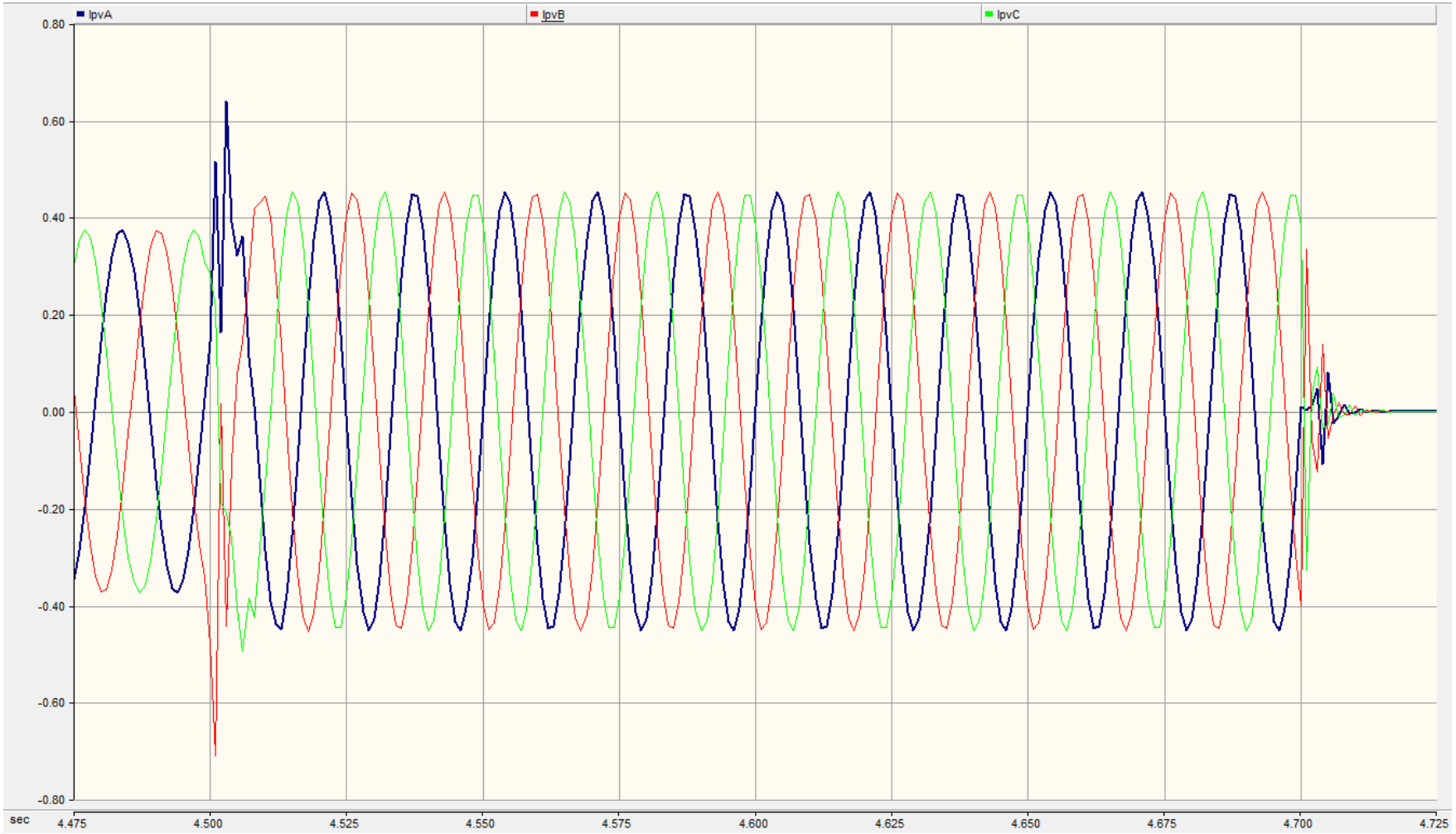
PV inverter: Generic Model



Generic Model:

- Operate for 4 to 10 cycles after a fault incident even if the PCC voltage drops below 50%.
- The current is usually between 100% and 120% of the rated power of the inverter.
- The current contribution level is a function of the voltage at the terminal of the PV inverter (PCC) during a fault and thereby the type and location of the fault.

PV inverter: Generic Model



PV inverter short circuit current contribution

- The PV inverters are found to detect the fault in two different ways:
  - Internal under voltage protection
  - Current and voltage unbalance
- Angle of fault currents
  - **The PV inverter fault current:** in phase with the voltage measured on its terminals before the fault occurred.
  - **The system fault current:** phase shift of approximately 80-90 degrees with respect to the system source voltage, depending on the X/R ratio.
  - => vector summation results in smaller values compared to an arithmetic summation.
- Frequency of PV inverter fault current:
  - Too low voltage at the terminal to determine frequency and phase angle
  - => the PLL of the inverter will suddenly change the frequency from +1 Hz to +10 Hz.
  - => the vector of the PV inverter current will rotate with respect to the system fault current.

IEC 60909:2016 – Short circuit contribution from full size converters

- IEC 60909-0:2016 Short-circuit currents in three-phase a.c. systems - Part 0: Calculation of currents
  - New: short circuit contribution from power station units with full size converters (for instance PV) and from wind power station units with doubly fed induction generator and full converters.
- Full size converter short circuit current contribution
  - Modelled in positive-sequence system by a current source
    - data should be provided by the manufacturer for the different types of short circuits
    - the short circuit current contribution from the equivalent voltage sources are calculated as earlier, however, the current contributions from the full size converts are added to this value
  - If the short circuit contributions from the converters are not higher than 5 % of the initial short circuit without these power station units, their contribution may be neglected.
  - Power station units with full converter are neglected when calculating the DC component of the short-circuit current.
  - The peak current of the converter contribution is square root of 2 times the rms value.
  - IEC 60909 does not consider the dynamic response and frequency changes of converter
    - simulations in the time-frame is needed in order to achieve a more accurate current contribution from converters.