Safe operation of photovoltaic systems in households with safety-plug connection

Technology
Arts Sciences
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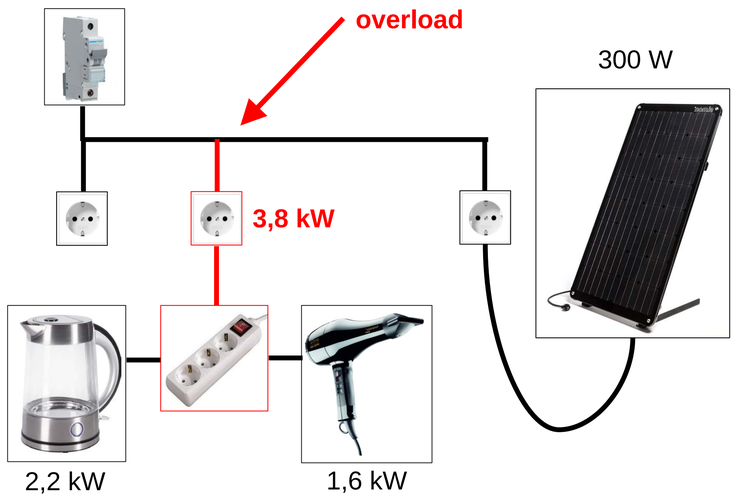
B. Sc. Leonard Schwochow, B. Sc. Sebastian Kersten

Small PV-systems have great potential to increase the share of renewable energy being used in every household. Due to their small design and safety-plug connectivity, they can be installed on balconies or facades by everyone. Depending on the actual load situation, the PV-system needs to stop feeding to prevent overloads. Therefore, a load situation estimation must be done by every PV-system.

Motivation

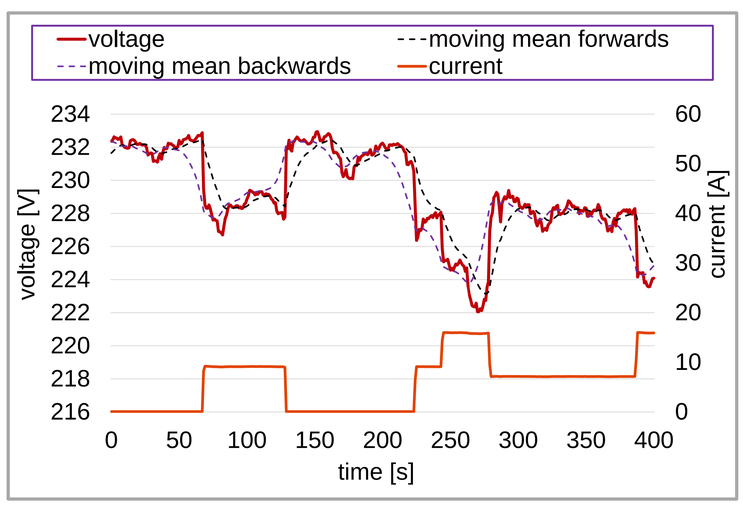


The fuse doesn't trip. No overload prevention is given. A PV-system has to detect this load situation and stop feeding.

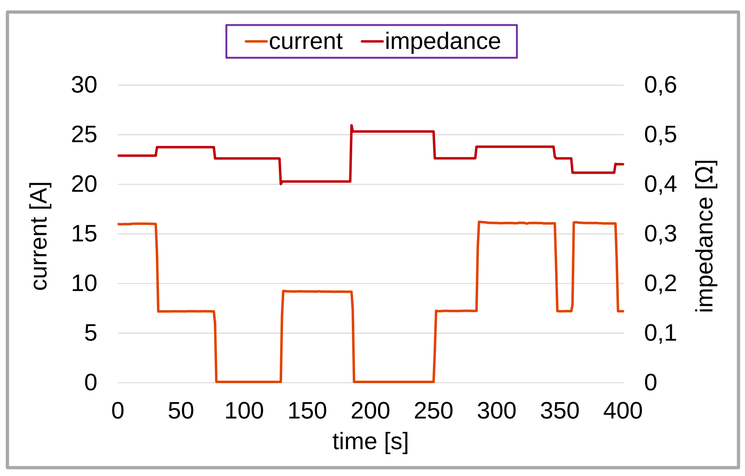
Load determination

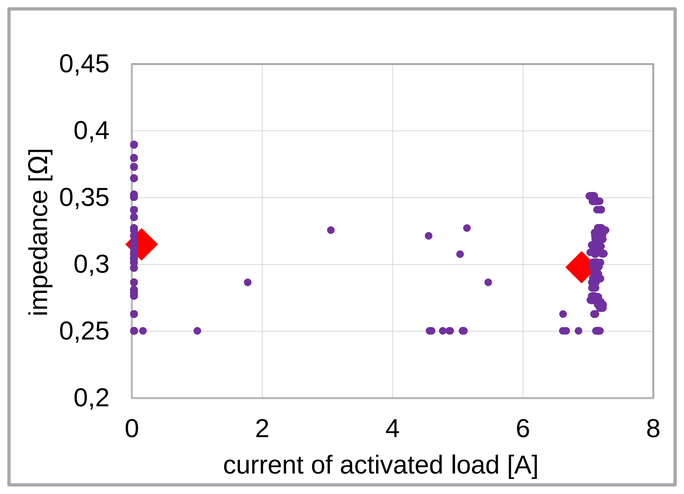
via grid impedance

When a load is activated, a voltage jump can be seen. By measuring voltage and current differences, the grid impedance can be calculated.



Voltage trends show some kind of flicker, whereas the current trend stays relatively smooth. For smoothing the voltage trend a moving mean function was used.

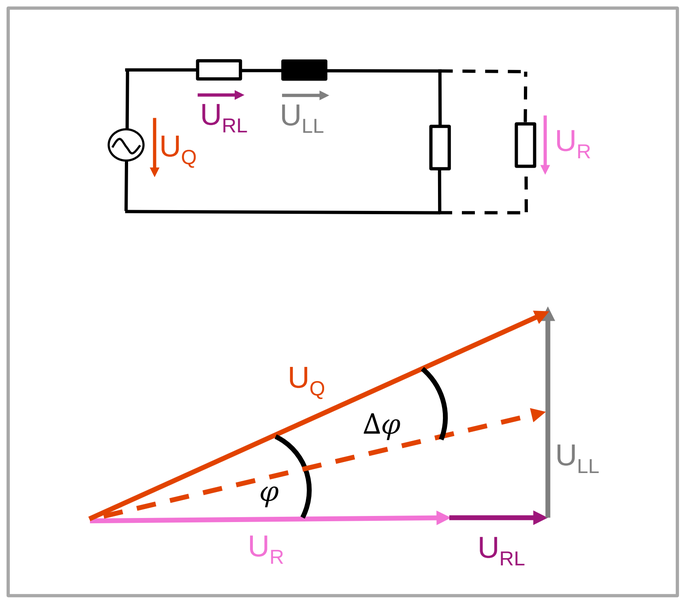




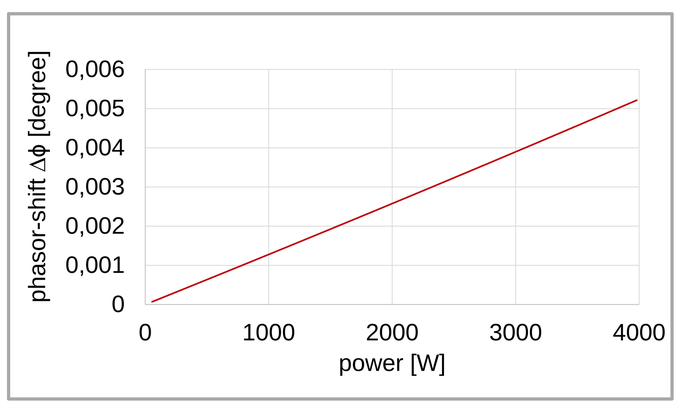
The grid impedance fluctuates naturally. Loads have a very small influence on the impedance.

via phasor-shift

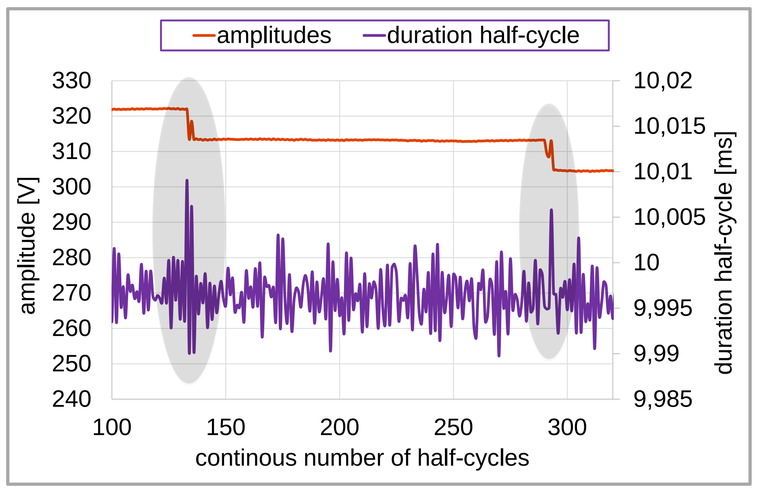
A wire has an ohmic and a indictive share in its complex impedance. Because of the inductivity a phasor-shift appears, when a load is being activated.



A pointer diagram can be made of the values of the amplitude and phasor-angle. This is more precise than analyzing only the grid impedance, because the inductive share is located only in the wire (simplified model). Its influence depends on the current flowing through the wire, which again is proportional to the wires load.



The phasor-shift related to the load power behaves linear. This was producible in simulations and measurements. From this, an exact determination of the load can be made. The phasor-shift appears with the same dependency for every string in the household. This is, because the inductivity of the cable to the house is a lot higher. No determination of the loads position can be done.



The duration of half-cycles in the grids sine has a natural variation, which is dimensioned in microseconds. The diagraph above shows, that load activations cause a delay of the same factor. Therefore it is difficult to estimate the load only by time delays. But still, some characteristics can be seen in the half-cycle durations. Fitting the values to a sine function and calculating the phasor-shift before an after load activation can help lowering the uncertainty.

via voltage trends

Voltage fluctuations caused by load activation show different heights depending on the distance to the point of measurement. This is caused by the relatively high resistance of the wires. An observation of these trends can help estimating how distant a load was activated if the load is known (phasor-shift).

Conclusion

- Only load estimation is possible
- For safe operation, a safety factor must be calculated
- Phasor-shift an voltage-jump methods have to be combined
- For more precise estimations, further investigations are necessary

Prof. Dr. Eberhard Waffenschmidt
CIRE – Cologne Institute for Renewable Energy
Technische Hochschule Köln

contact:
leonard_juergen.schwochow@smail.th-koeln.de
sebastian.kersten1@smail.th-koeln.de
Cologne University of Applied Sciences,
Betzdorfer Straße 2, 50679 Köln, Germany

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cire Cologne Institute for Renewable Energy