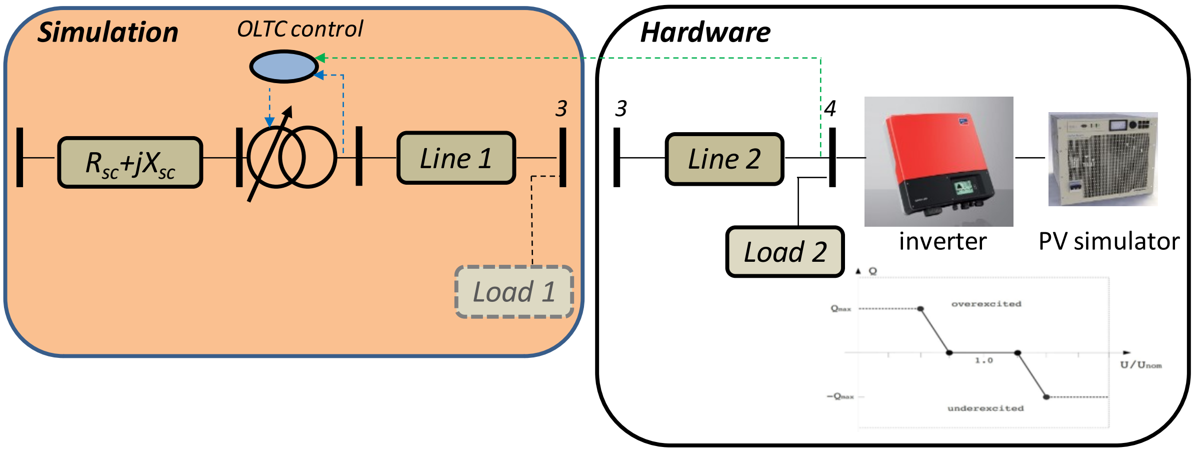
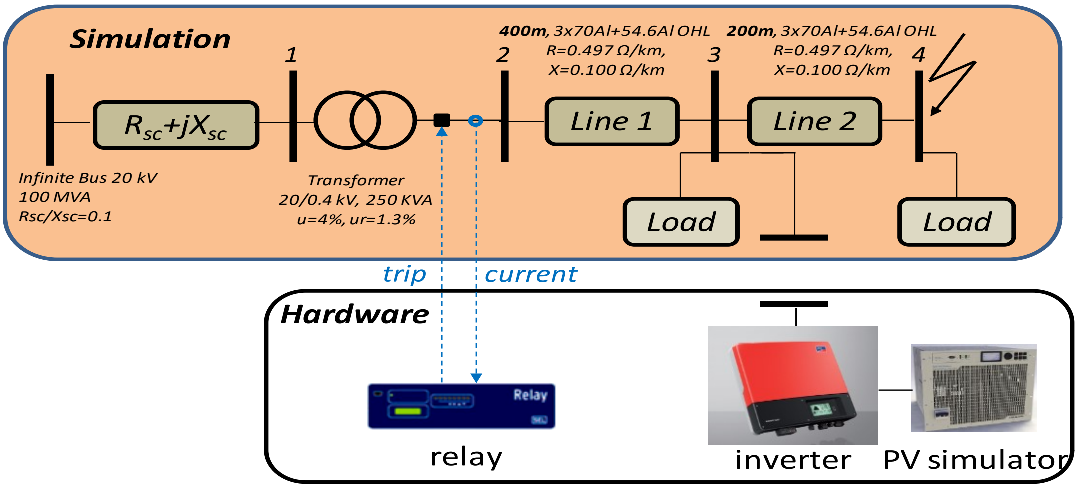
1st Laboratory Exercise: "Contribution of distributed generation to voltage control – behavior of distributed generation during short-circuits"

1st experiment: This laboratory experiment examines the effect of Distributed Generation (DG) on the voltage of the point of common coupling and the possibility of its contribution to voltage control. A resistive-reactive (RL) load and a Photovoltaic (PV) inverter are connected at the end of a long distribution line, as shown in the figure below. A part of the distribution line and a transformer equipped with On-Load Tap Changer (OLTC) are simulated in the Real-Time-Digital-Simulator (RTDS®), whereas another part of the line, the PV inverter and the load are physical equipment. The PV inverter can support the voltage by either using local control (Q(V) droop and cosφ(P)) or remote control (active and reactive power set-points) to provide ancillary services to the grid.



2nd experiment: This laboratory experiment examines the behavior of inverter based Distributed Generation during short circuits. A hardware PV inverter is connected to the real-time distribution network shown in the figure below. A symmetrical three-phase short circuit is applied on the most remote bus of the network, which causes a 30% voltage drop on the point of common coupling of the inverter. The short-circuit current of different PV inverters, as well as the contribution of the grid are measured. In addition, the operation of protection devices (industrial relays) during several faults is tested.



Queries:

1a) At which of the following conditions of load and distributed generation does the voltage rise problem appear in distribution networks?

i) Maximum Load – Minimum Generation *ii) Maximum Load – Maximum Generation*

iii) Minimum Load – Minimum Generation *iv) Minimum Load – Maximum Generation*

1b) What are the main methods of mitigating the voltage rise problem which is caused by the high penetration of DG in distribution networks?

1c) A 10 kW three-phase load (0.9 inductive power factor) and a 50 kW three-phase PV inverter, (operating at unity power factor, with the capability of 0.8 leading or lagging power factor) are connected at the end of a 600 m long Low Voltage line (R=0.497 Ω/km and X=0.1 Ω/km). The voltage at the infinite bus is considered equal to nominal V_n=400 V line-to-line.

i) Calculate the voltage (using the approximate formula) at the load-inverter bus.

ii) How much reactive power does the inverter have to produce or absorb in order to reduce the voltage at the point of common coupling to 1.055 p.u.? At which power factor will the inverter be operating? Is the inverter capable of producing-absorbing the necessary reactive power? If not, what other action could it perform in order to reduce the voltage to the desired value?

iii) Calculate the voltage at the load-inverter bus when R/X=1 and when R/X=0.1, for X=0.06 Ω and unity power factor of the inverter. What do you observe?

2a) Which factors influence the short-circuit current of inverter based Distributed Generation? Which approximate values are used at practical calculations?

2b) What is the relation (qualitative) of the aforementioned current with the short-circuit current of a rotating DG of equal power (directly connected to the grid)?

2c) Calculate the short-circuit current at a symmetrical three-phase short-circuit on bus #4 of the second figure. Ignore the loads and the PV inverter.