Droop Control in DC Grids for Kitchen Appliances to avoid Power Congestion

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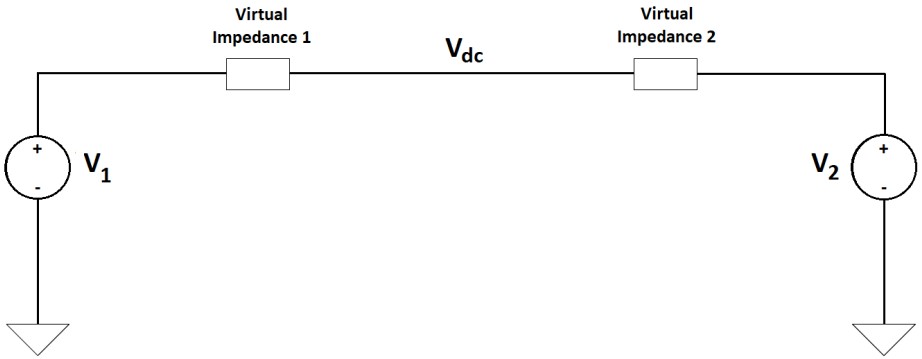
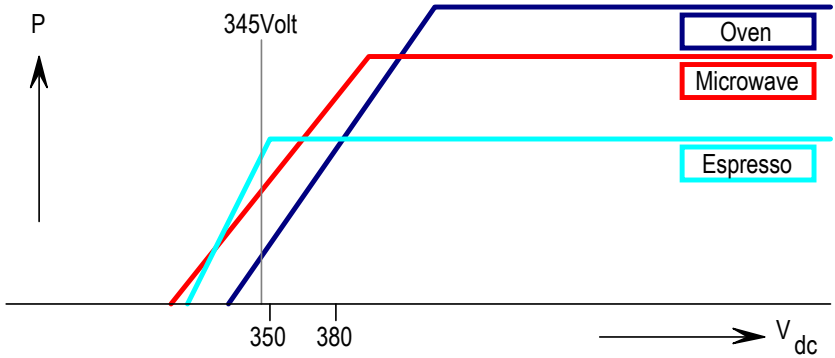
Basics of droop control



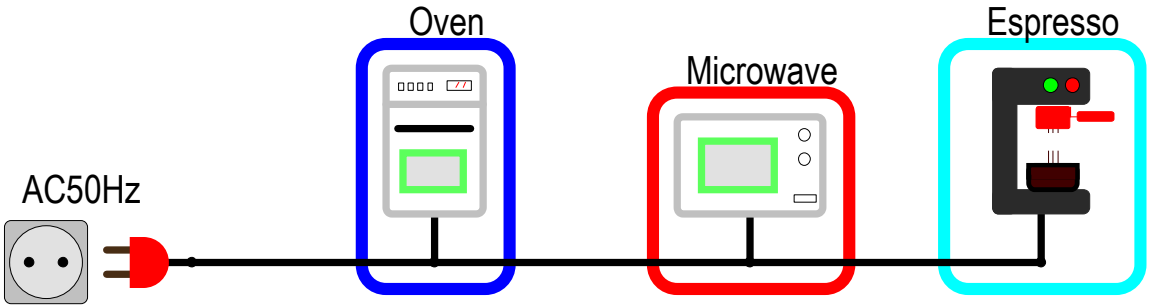
Voltage V_{dc} depends on the current through the virtual impedance, here represented by two resistors between the two voltage sources V_1 and V_2.

Droop charactersitics



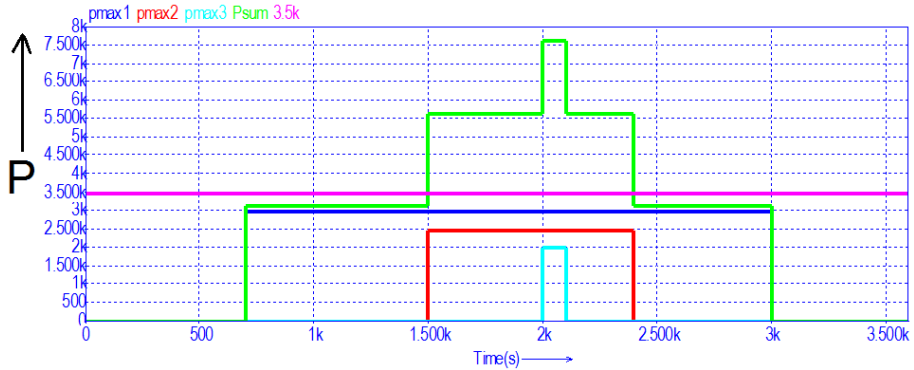
Droop control characteristic per appliance, oven(blue), microwave(red) and espresso machine(lightblue).

AC Appliances



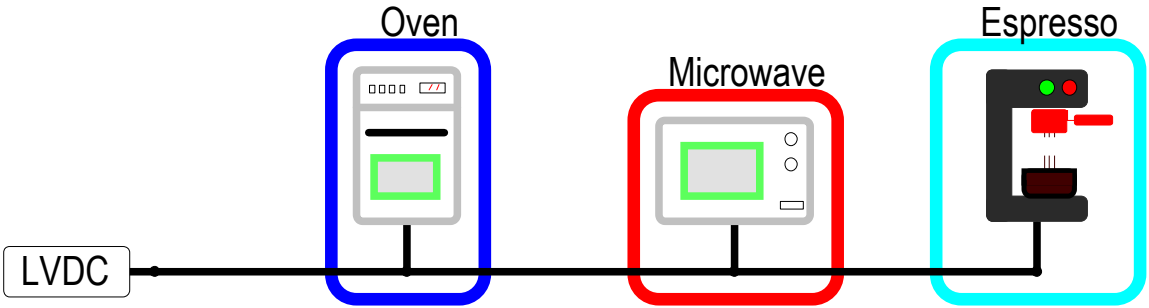
Oven, microwave, and espresso machine connected via a single power strip to an AC mains outlet.

AC power



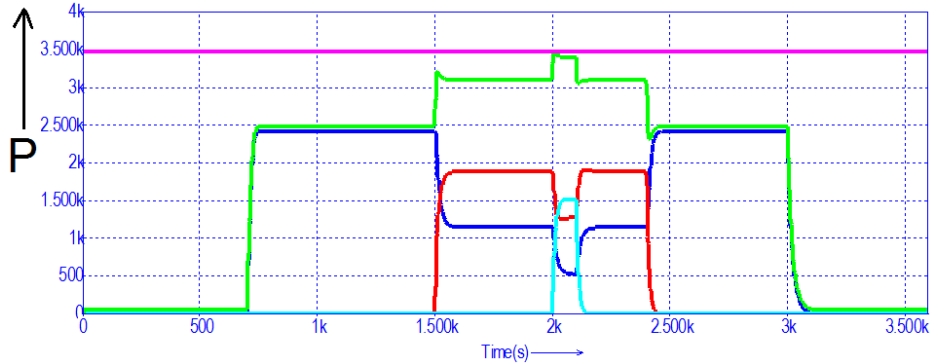
AC Power consumption in Watt(Y-axis) for the oven(blue), microwave(red) and espresso-machine(light blue). Total power consumption(green) is larger than the maximum power consumption allowed by the circuit breaker(magenta).

DC Appliances



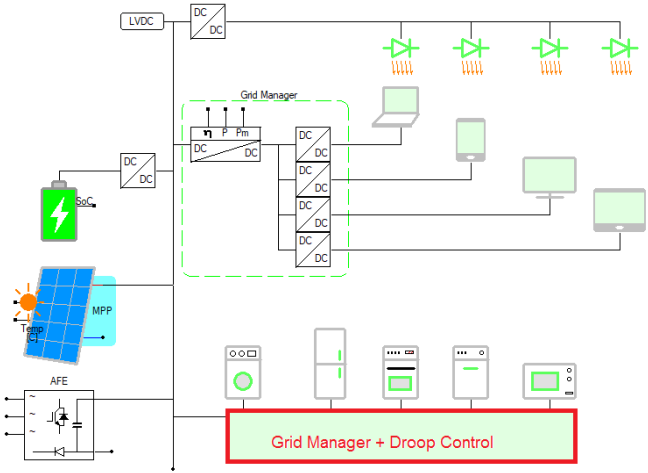
Oven, microwave, and espresso machine connected via a single line to a DC grid.

DC power

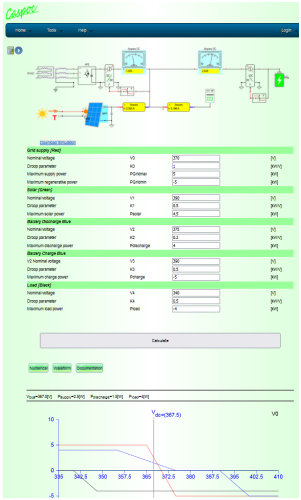


DC Power consumption in Watt(Y-axis) per appliance, oven(blue), microwave(red) and espresso-machine(lightblue), total power consumption(green) below the maximum allowable power consumption limit(magenta).

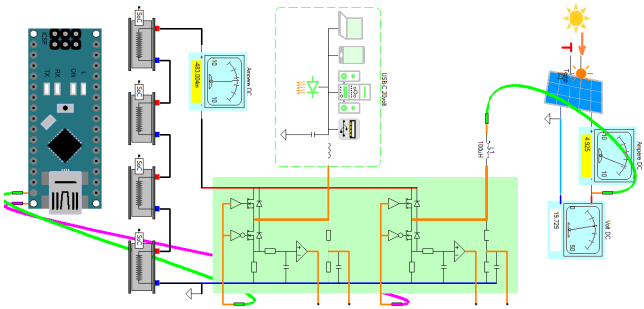
Nano Grid



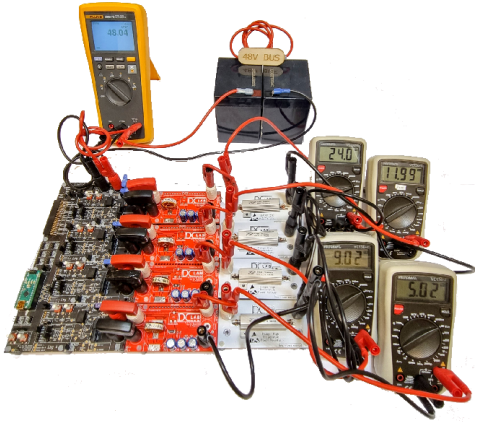
Typical home DC grid with two grid managers.



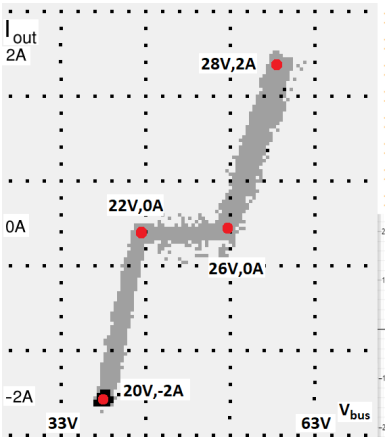
Design tool to define the droop control characteristics.



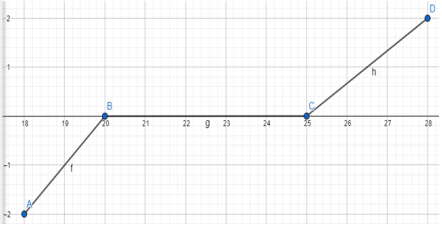
Simulation in Caspoc of droop control and two legs.A solar panel is controlled from leg 1 using a build-in maximum power point tracker, while leg 2 includes the droop characteristic for an USB-C connector feeding multiple devices



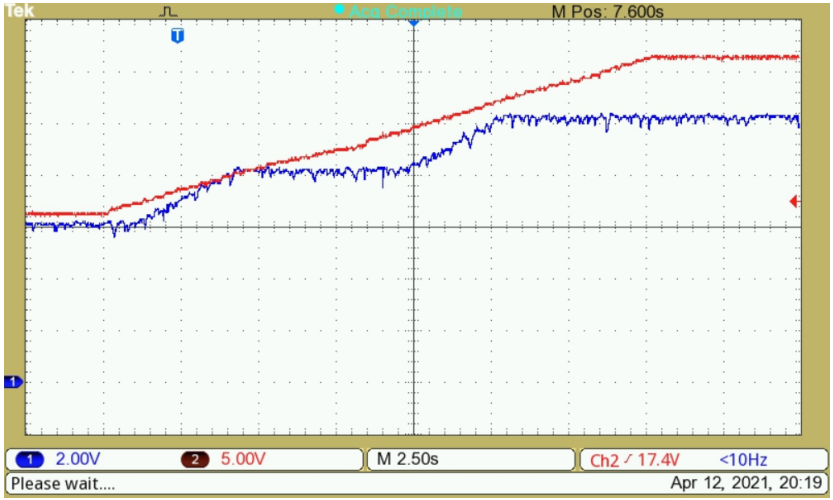
The U4L laboratory setup is connected to a 48Vdc nominal bus. Every leg is connected to a 10Ω resistive load, creating four nominal voltage levels 5V, 9V, 12V, and 24V.




```
DroopControlCurve[Legl][0].Voltage = 20;
DroopControlCurve[Legl][0].Goal    = -2;
DroopControlCurve[Legl][1].Voltage = 22;
DroopControlCurve[Legl][1].Goal    = 0;
DroopControlCurve[Legl][2].Voltage = 26;
DroopControlCurve[Legl][2].Goal    = 0;
DroopControlCurve[Legl][3].Voltage = 28;
DroopControlCurve[Legl][3].Goal    = 2;
```



The static droop characteristic of the leg producing 24volt, compared to the implementation of the droop characteristic in the Arduino Nano.



Dynamic behavior, increasing voltage(Red trace) and increasing usage of power(Blue trace).

Conclusion

- Power Congestion Management requires control of the power flow
- AC grid
  - Circuit breaker
  - Over-consumption means no power
- Droop Control in DC grid:
  - Equally share power
  - Power consumption controlled by DC voltage level
- Educational Training using the Universale Four Leg

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www.dc-lab.org www.caspoc.com