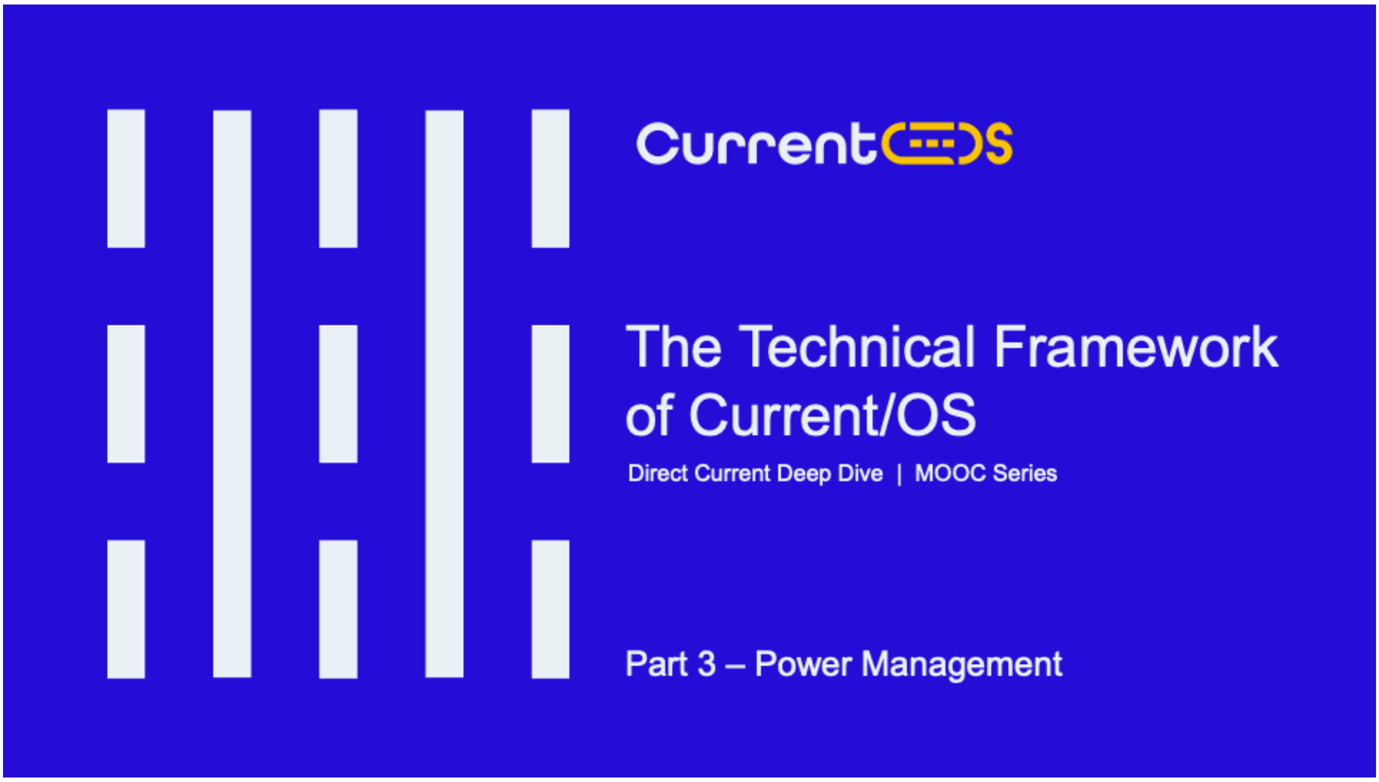


Welcome to “Direct Current Deep Dive: Exploring the Technical Framework of Current OS” , a MOOK designed to dive into the principles behind Current OS technical decisions and their role in defining the standard for Direct Current electrical systems, also commonly referred to as DC-coupled systems, or DC microgrids

This video is part 3 of a six-part series. Explore the remaining videos on the Current OS YouTube Channel to continue learning about the world of Direct Current.

In this video, we’ll explain the underlying principles that drive Current OS's technical choices on power management with droop control. Resilience and convergence are at the core of the design. We’ll see how Current OS installations are self-regulating, minimizing demand to the public grid while stabilizing fluctuations for smoother integration with the public grid.

Many people transitioning from AC often ask what does DC bring to the table?

There are areas where direct current can offer advantages that are difficult to achieve with alternating current.

A helpful analogy is the difference between a tablet and a laptop. While both can send emails and stream videos, they serve distinct purposes. In practice, we might use a laptop for work and a tablet at home to watch Netflix. Though their functions overlap, tablets are often more convenient, fluid, and better suited to specific situations.

The same principle applies to AC and DC. Partners in Current OS agree that DC offers more refined, sophisticated power flow management capabilities. These advanced features enable new services and possibilities that AC systems cannot provide as effectively.

In the next animation, we’ll illustrate this concept. Rather than diving into technical details, we’ll focus on showing the value DC brings to clients.

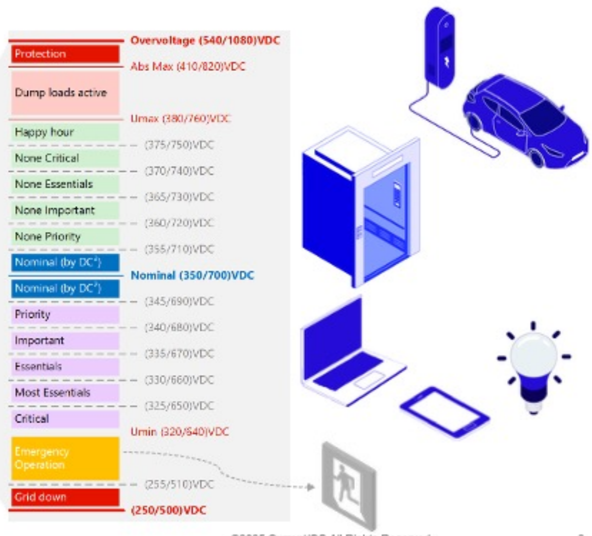
Defining Standards for Direct Current Electrical Systems Current/OS

Droop control introduction

- The installation operates with voltage-driven modes with droops
- Each converter senses the voltage and adjusts according to its droop settings :

Voltage	Sources	Loads
goes up ⬆	reduce their contribution	“accelerate” or run at max power
goes down ⬇	increase their contribution	“slow down” or disconnect

- **This ensures resilience, power efficiency and scalability**



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What can be achieved with direct current that is not possible with AC?

DC allows voltage to act as a signal, guiding the behavior of every source and load in the system. When the voltage rises to the upper half of the nominal band (for example, above 350 volts but below 380 volts), sources tend to reduce their contribution. This could mean slower battery discharge, reduced energy import from the public grid, or even scaling back the contribution of photovoltaic panels once a certain threshold is reached.

At the same time, when the voltage rises, loads respond by accelerating. For instance, electric vehicles charge at full power, and water heaters operate at their nominal capacity, effectively "speeding up" consumption.

Conversely, when voltage drops, each source works to increase its contribution. Batteries discharge faster, within the limits of the converter's nominal power, and the system absorbs more energy from the grid as needed. Meanwhile, loads adjust by "slowing down." Water heating and EV charging rates are reduced, aligning with available power.

In DC systems, we refer to "accelerating" and "slowing down" to describe the dynamic adjustments of power flow.

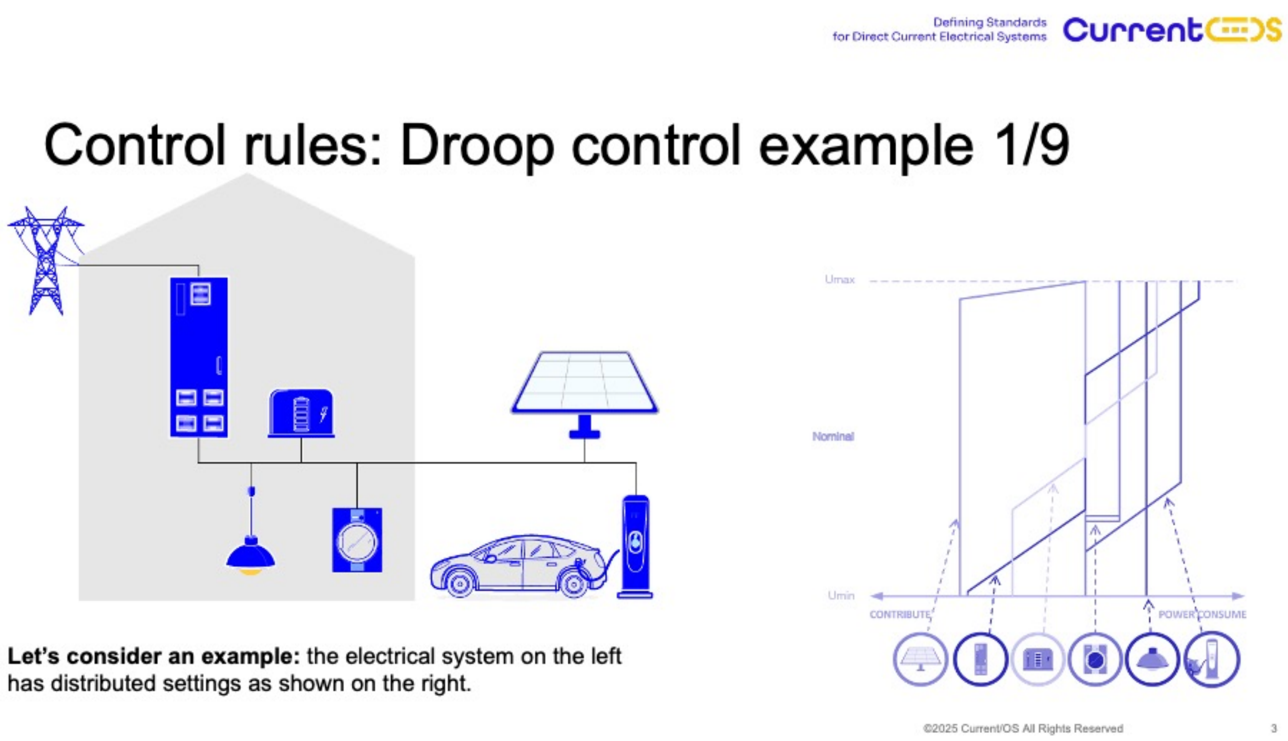
This highlights a key difference between AC and DC. In AC systems, most actuators function as contactors, toggling between on and off. Think about the day night switch for a water heater—it’s either on or off.

In DC, thanks to power converters embedded throughout the system, every source and load effectively has its own variable-speed controller. This allows for gradual, precise adjustments.

The benefits are significant. By continuously adjusting sources and consumers, DC systems can reduce the power demand on the public grid by at least half, and sometimes up to five times. For the same building, this ability to dynamically balance supply and demand drastically lowers the required power at the grid connection point.

In a world where public grids struggle to meet the rising demand for EV charging stations while also handling surplus energy from renewables, having a system that can continuously "accelerate" and "slow down" is a game changer.

This capability has been demonstrated in numerous installations, where Current OS solution has been operational for several years.



To make it clearer, the concept will now be illustrated with a short animation.

Let's consider a simple DC microgrid setup.

It includes an AC DC Current OS converter, a battery storage system, and photovoltaic panels in the parking lot, alongside an EV charging station. Within the building, there are typical loads such as lighting and a washing machine.

Each device in this setup monitors the voltage on the common bus. The advantage of voltage is that it is the same for all devices, serving as a universal signal to guide their behavior. Based on the voltage level, each device reacts accordingly.

This behavior is illustrated on the chart at the right hand side:

- The vertical axis represents voltage—high voltage at the top and low voltage at the bottom.
- The horizontal axis shows the device's behavior: on the left, the device contributes power; on the right, it consumes power.

Each source or load has a typical setpoint curve reflecting its behavior. Let's look at some examples:

Photovoltaic panels follow a straightforward curve. They contribute all available power regardless of voltage. However, when the voltage reaches a high threshold, their contribution begins to reduce—this is a typical behavior for photovoltaics.

The EV charging station has the opposite type of curve. High voltage signals that sufficient power is available, so the EV charges at nominal power. As voltage drops, the charging rate gradually reduces until there is insufficient power for the vehicle, at which point charging stops. This reduction happens smoothly, avoiding abrupt transitions.

More sophisticated contributors and consumers, like the public grid connection, operate differently. When voltage is low, power is imported from the grid. As the voltage rises, grid import reduces and eventually stops to minimize costs. If the voltage continues to rise due to excess power, the system begins exporting energy to the grid.

It’s important to note that these curves are fully programmable, this is just an example. For each project or installation, it is up to the system designers and engineers to define these thresholds based on specific client needs. For instance, some clients prioritize minimizing grid consumption and might reduce imports as soon as voltage starts rising. Others may prioritize maximizing power delivery to loads and program their curves differently.

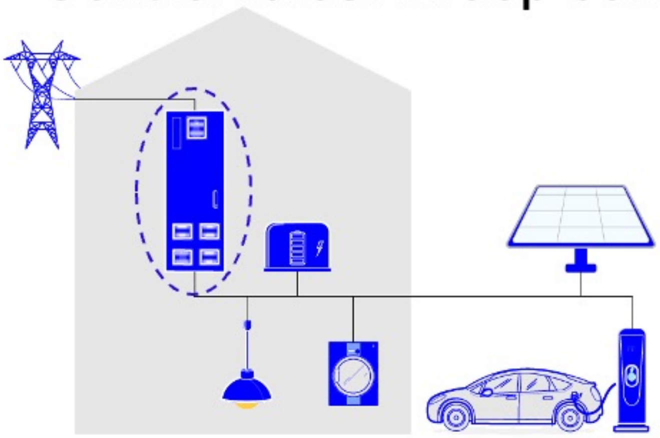
The battery system behaves similarly to the grid connection. It contributes power when voltage is low, then gradually reduces its output and eventually stops. When there is surplus power, the battery shifts to charging. In this example, the battery is programmed to contribute before importing from the grid and to discharge fully before exporting power to the public grid. This setup supports an energy self-consumption strategy, although it can be adjusted for other priorities.

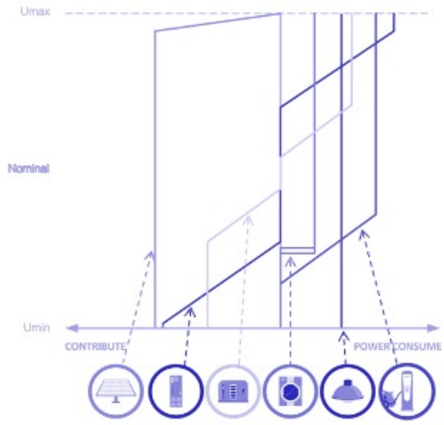
Now, let’s look at the loads. Some loads, like EV chargers, can adjust their power consumption based on the available voltage. However, for critical loads like lighting, this isn’t acceptable—they must operate at nominal power across the entire voltage band to ensure uninterrupted functionality.

Finally, there are simpler loads, such as the washing machine in this example, which do not have gradual power adjustment. They operate at nominal power and stop entirely when the voltage drops too low. A small hysteresis is built in to prevent instability caused by frequent starts and stops.

In summary, each source or load in a DC microgrid monitors voltage and uses a software-defined setpoint control curve to determine its behavior. This flexibility allows the system to adapt dynamically, balancing power contributions and consumption efficiently.

Control rules: Droop control example 1/9

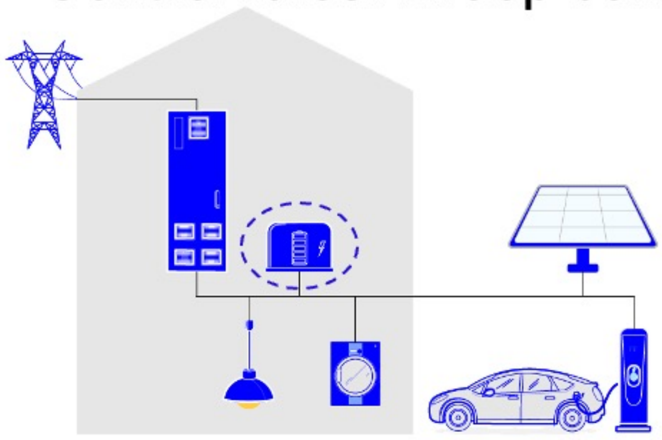


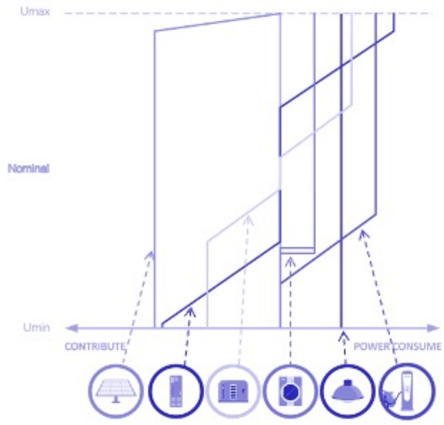


Let's consider an example: the electrical system on the left has distributed settings as shown on the right.

It includes an AC DC Current OS converter,

Control rules: Droop control example 1/9





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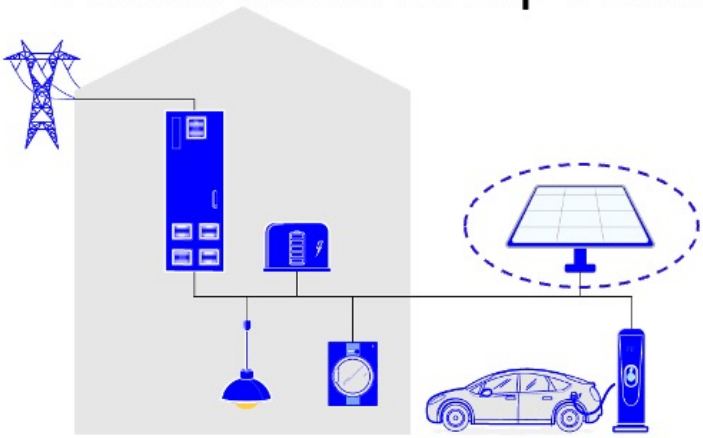
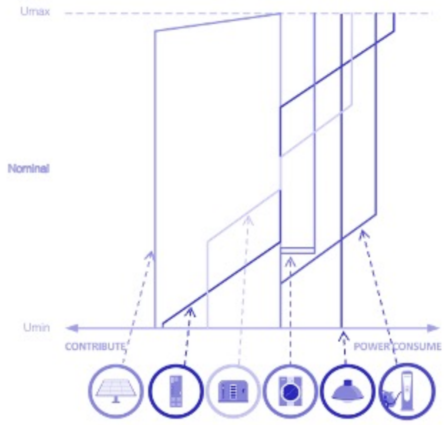
a battery storage system,

Control rules: Droop control example 1/9





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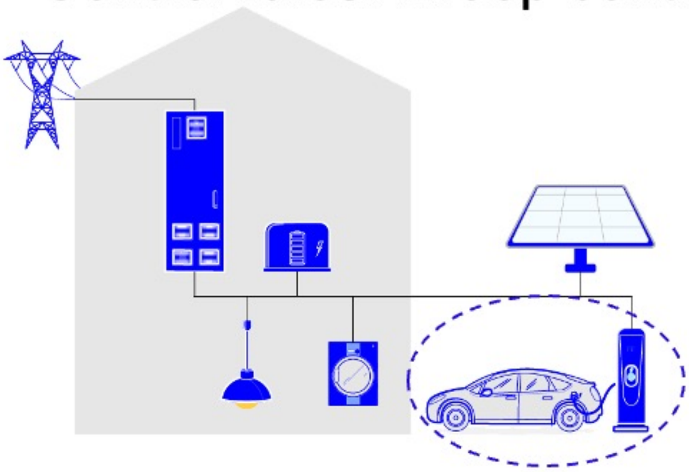
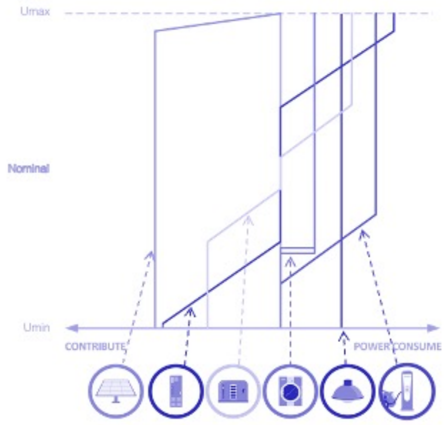
Control rules: Droop control example 1/9





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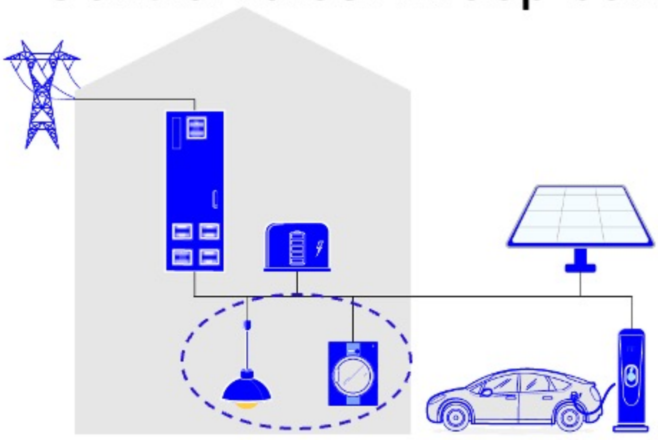
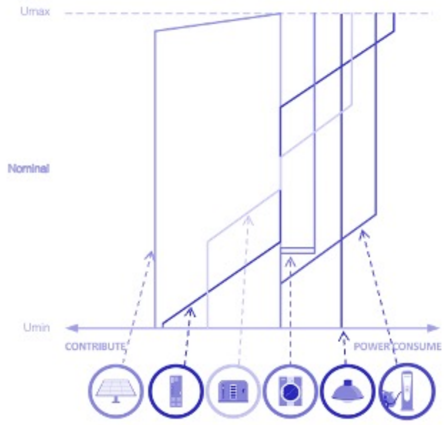
Control rules: Droop control example 1/9





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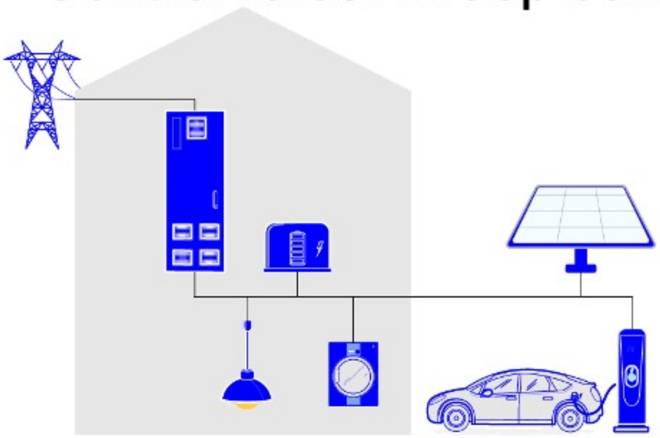

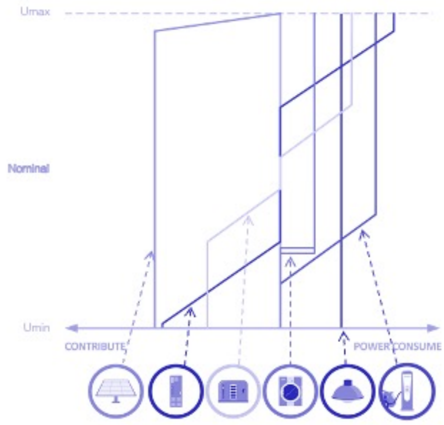

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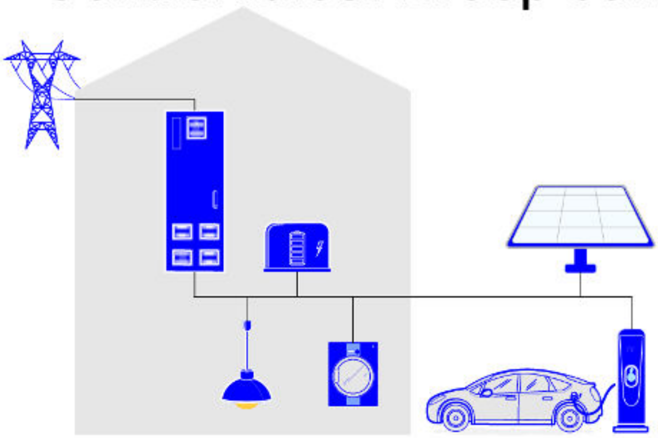

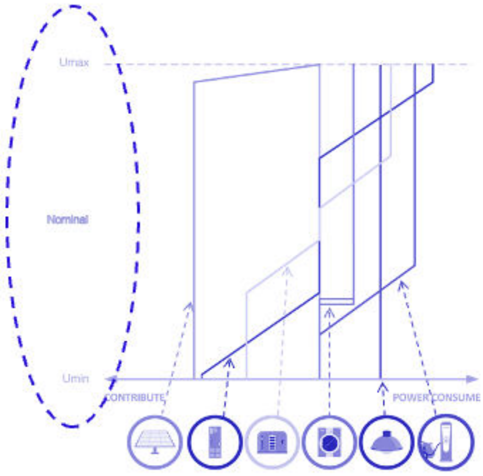

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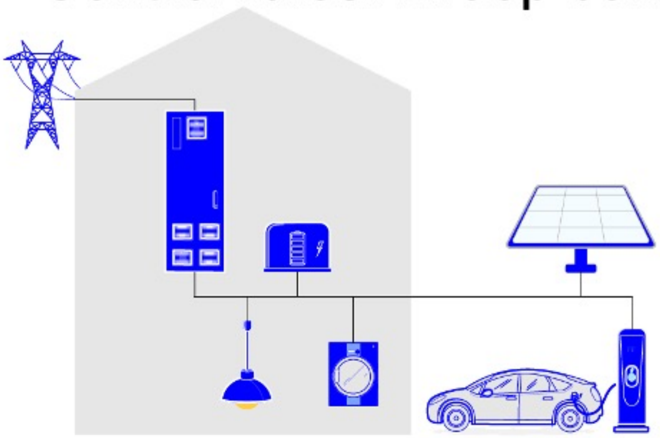

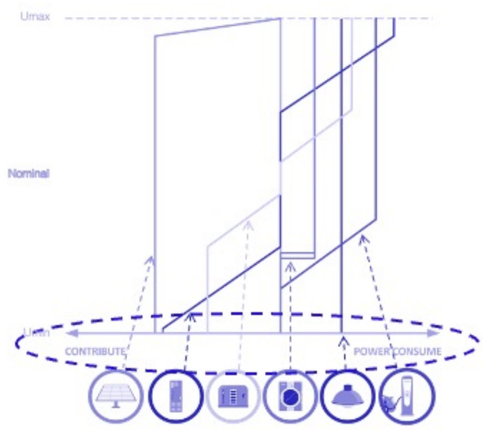

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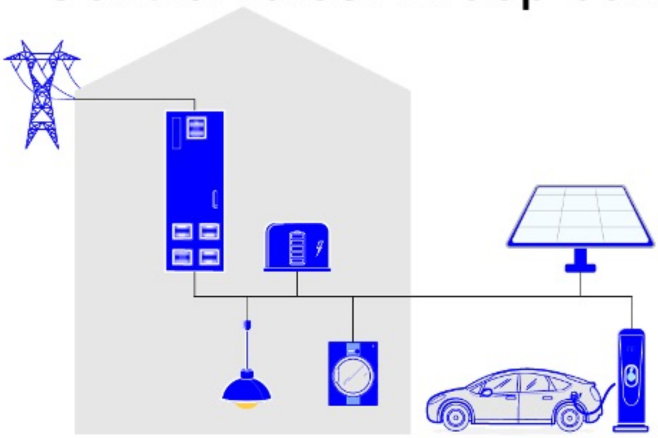

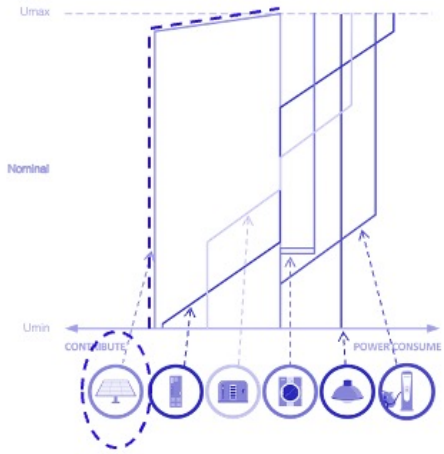

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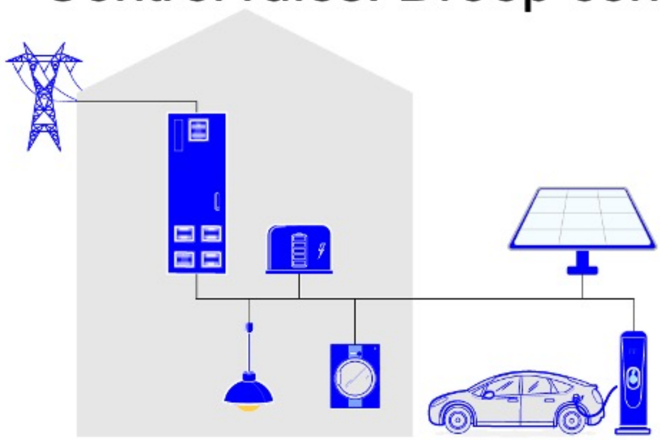
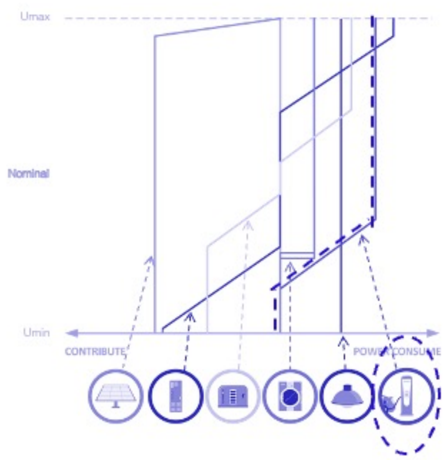
Control rules: Droop control example 1/9





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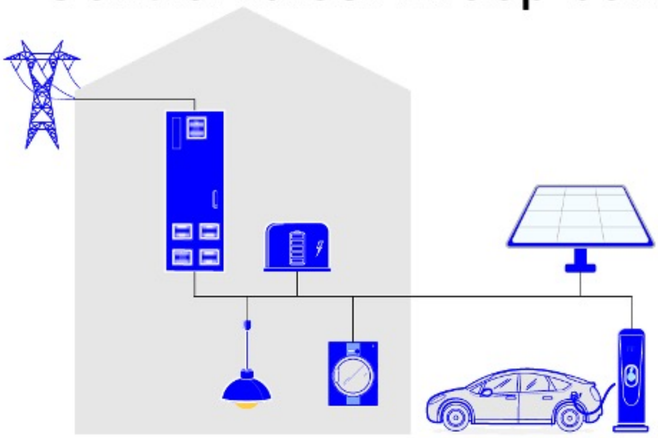
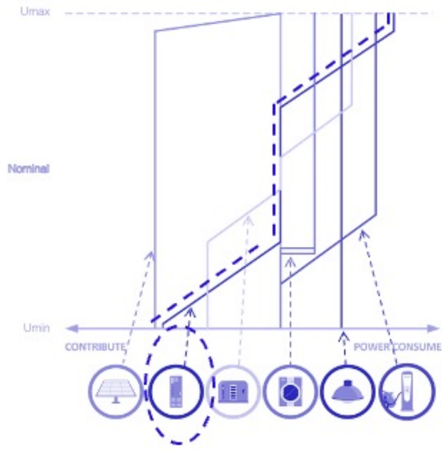
Control rules: Droop control example 1/9





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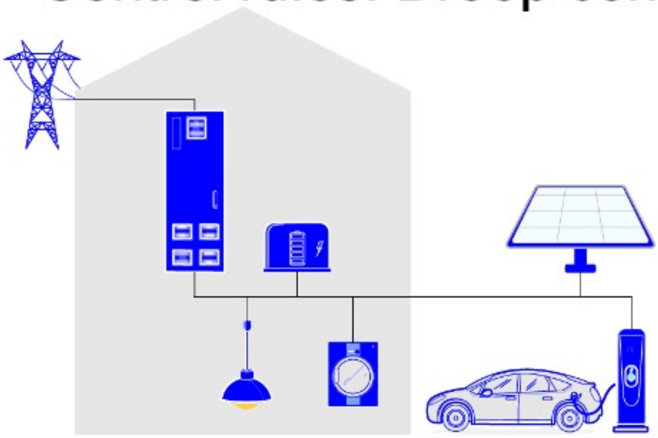
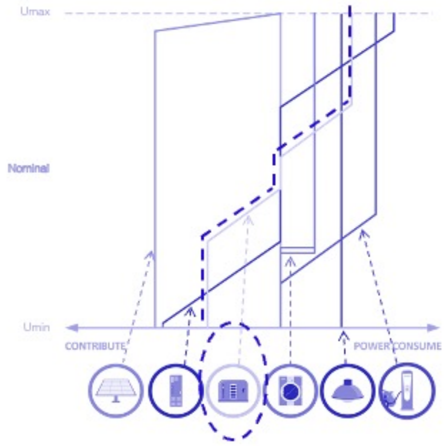
Control rules: Droop control example 1/9





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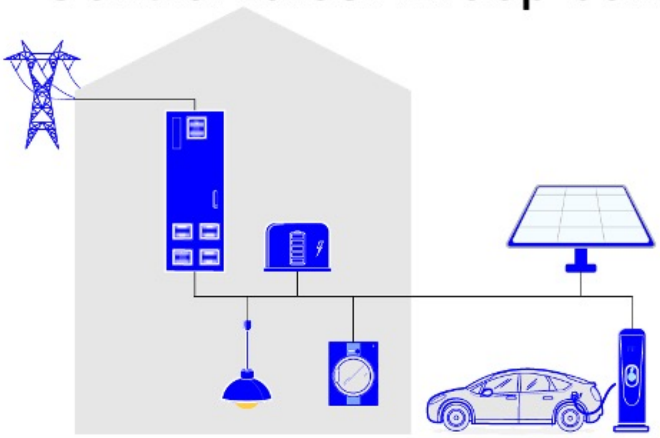
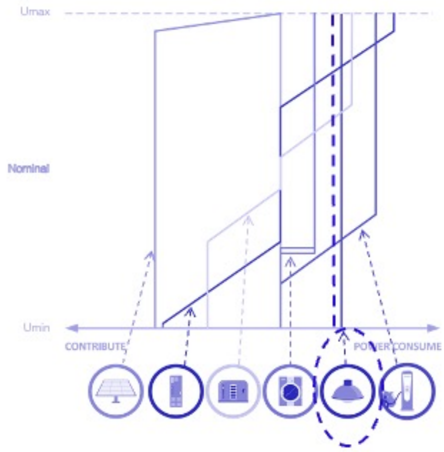
Control rules: Droop control example 1/9





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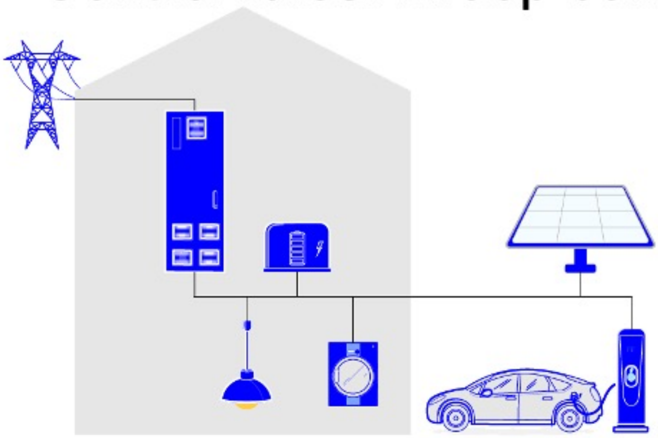
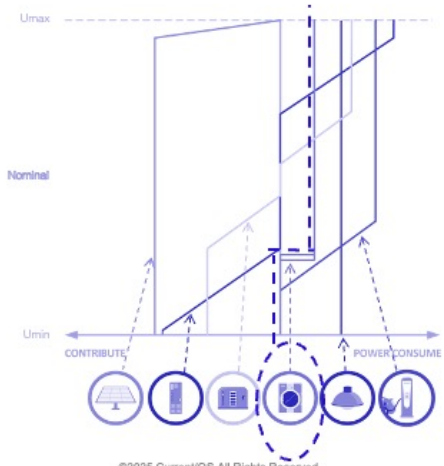
Control rules: Droop control example 1/9





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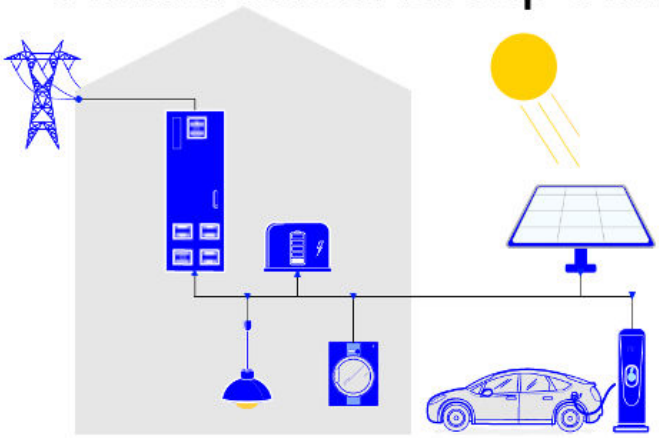
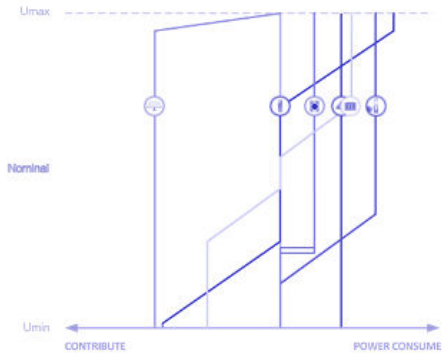
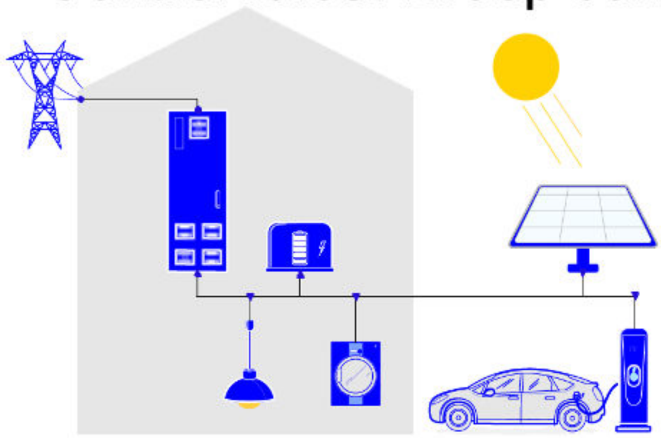
Control rules: Droop control example 2/9

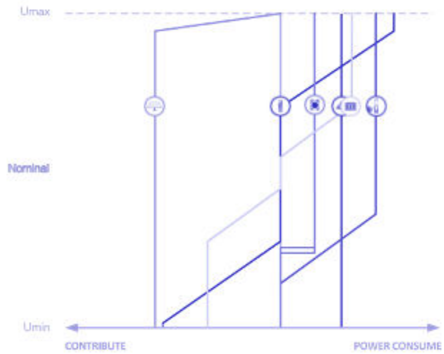




In sunny conditions, the voltage is high. It's happy hour! Loads are all powered, battery is charging and there is even room for a small export to the AC grid.

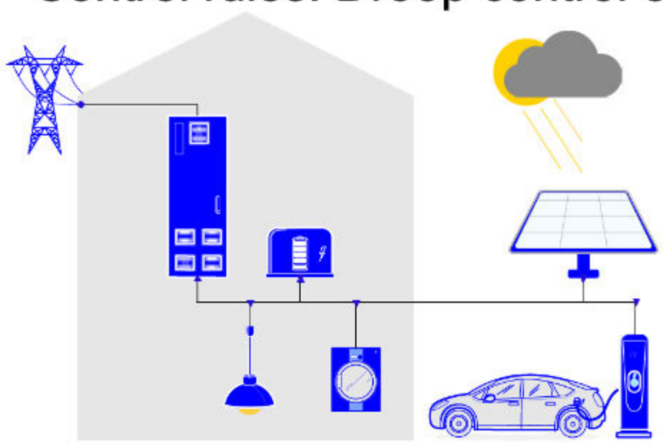
Control rules: Droop control example 3/9

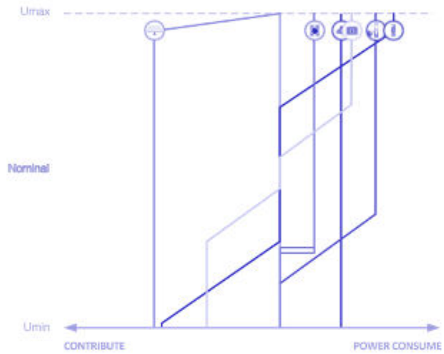




Sunny conditions continues, the battery is now full and not consumming anymore. The voltage is VERY high, happy hour continues! There is now full power export to the AC grid.

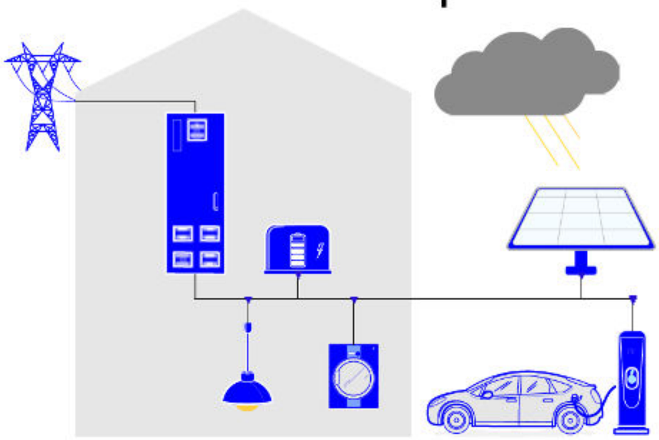
Control rules: Droop control example 4/9

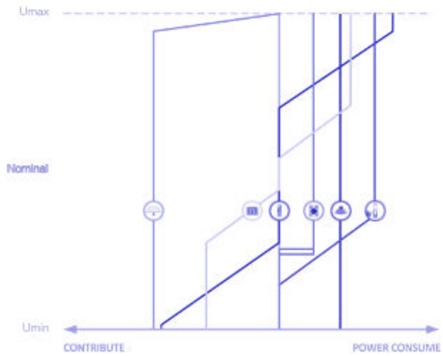




Cloud is coming reducing PV production. The voltage comes lower. Battery is dis-charging. Power remain enough to power all loads. But no more export to the AC grid.

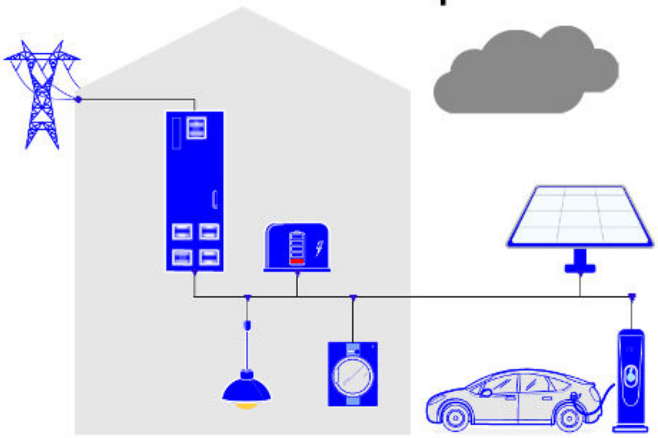
Control rules: Droop control example 5/9

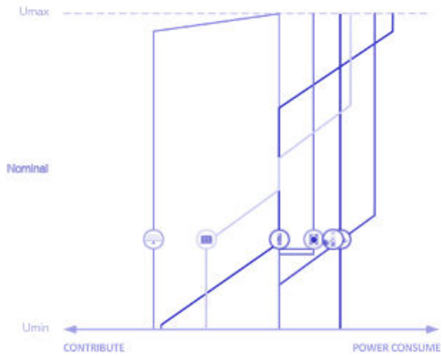




Clouds are now stopping PV production. The voltage is even lower. Battery is still discharging. But power is not sufficient to power all loads: the car charging has started to slow down.

Control rules: Droop control example 6/9

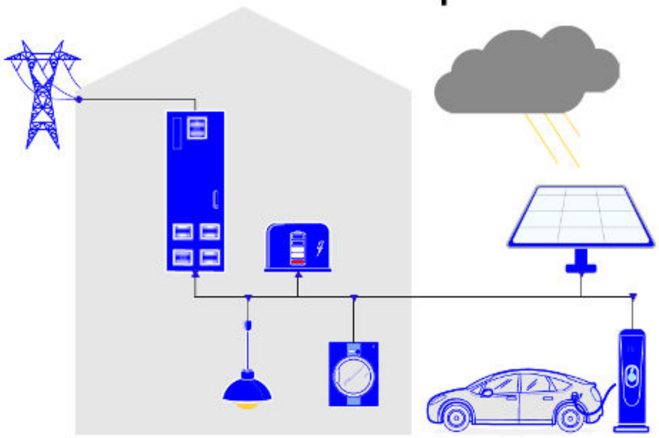


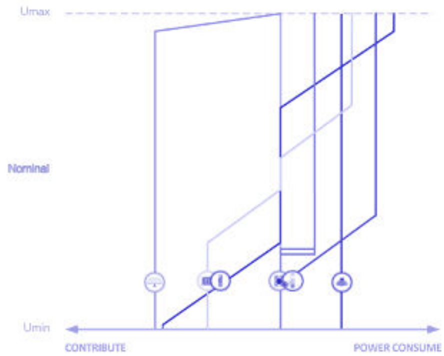


Clouds stays stopping PV production. The voltage reduces again and battery is now empty. Some Power is imported from the AC grid. The lights remains on but the washing machine is stopped, the car charging is very slow.

Note: in a real case the AC connection could be sufficient to power all loads.

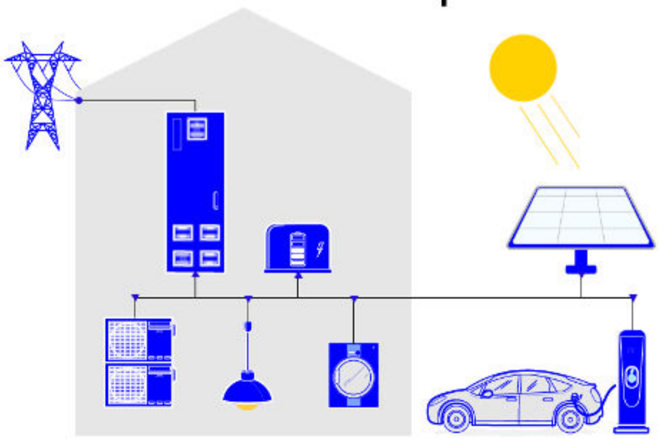
Control rules: Droop control example 7/9

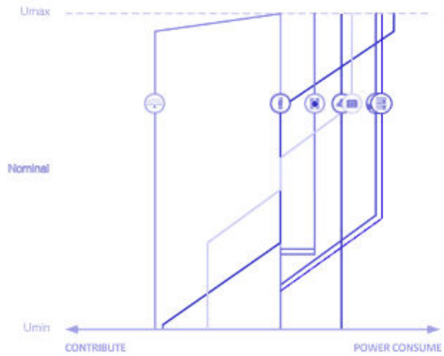




The sun is back. The voltage is high again. It's happy hour again !
Loads are all powered: the washing machine restarted. The car is charging at nominal power. Battery is re-charging. There is even room for a small export to the AC grid.

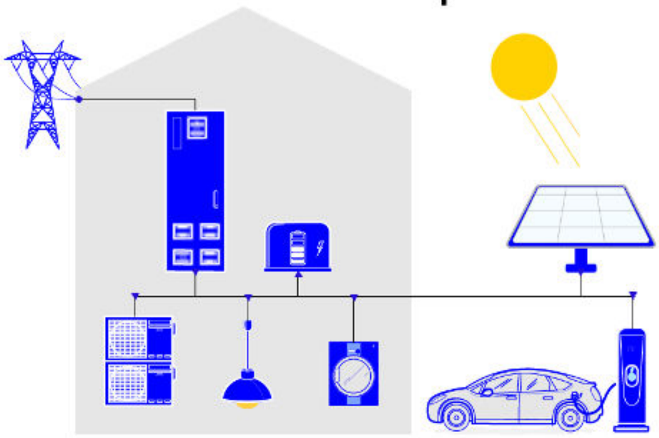
Control rules: Droop control example 8/9

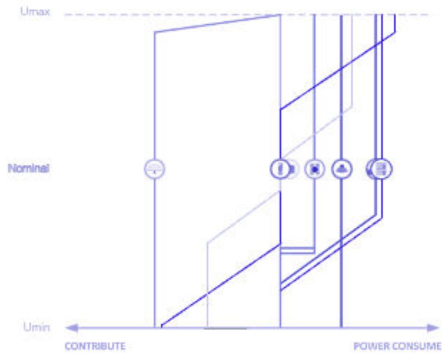




There is a new load added to the system.
The voltage goes to a new operating point. Power is enough to power all loads including the new one. But the battery is not charing anymore and export to the AC grid has stopped.

Control rules: Droop control example 9/9





There is a possibility to change the priorities though communication.
Change settings to force charging of the battery and import more power.
The voltage goes to a new operating point.

Defining Standards for Direct Current Electrical Systems CurrentOS

The Technical Framework of Current/OS

Check the other parts of the Direct Current Deep Dive | MOOC Series

This concludes the introduction of Current OS.

Want to learn more? Check out the other five Current/OS MOOC videos covering voltages, power management, electrical protections, precharging and earthing

Thank you for watching, see you in the next video!

Connect with the Current/OS team

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