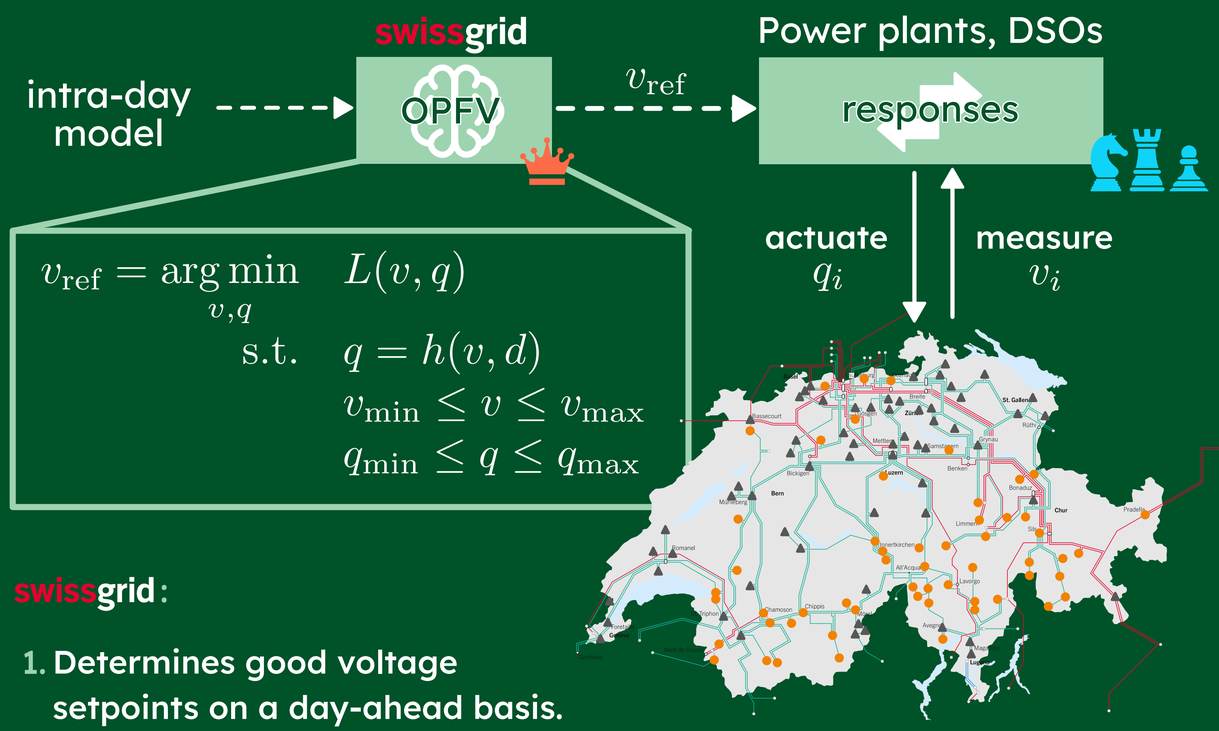
Procuring voltage support

Made in Switzerland

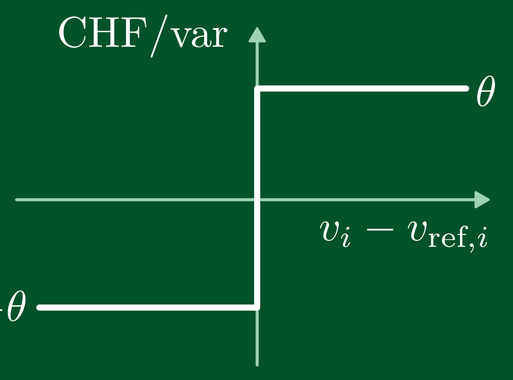


swissgrid:

1. Determines good voltage setpoints on a day-ahead basis.
2. Then, incentivizes resources to track the desired voltage profiles.

Incentive payments:

$$p(q_i, v_i; \theta) \approx \theta q_i \operatorname{sign}(v_i - v_{\text{ref},i})$$

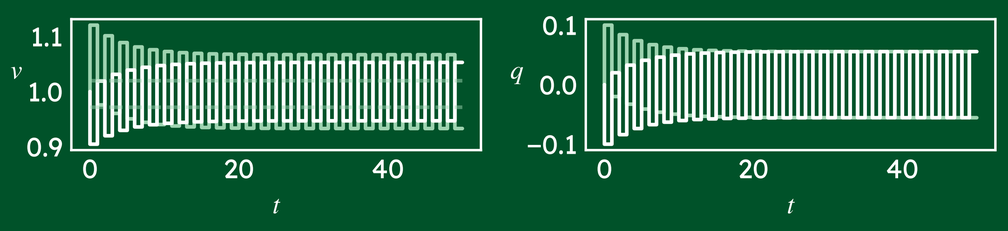


- proportional to $|q|$
- positive (reward) if "conform"
- negative (penalty) if "non-conform"

Should incentivize tracking of reference voltage

Inefficient: Incentive mechanism has not been designed to optimize operational costs.

Unsafe: Discontinuous incentive function promotes destabilizing responses.



How much for your services?

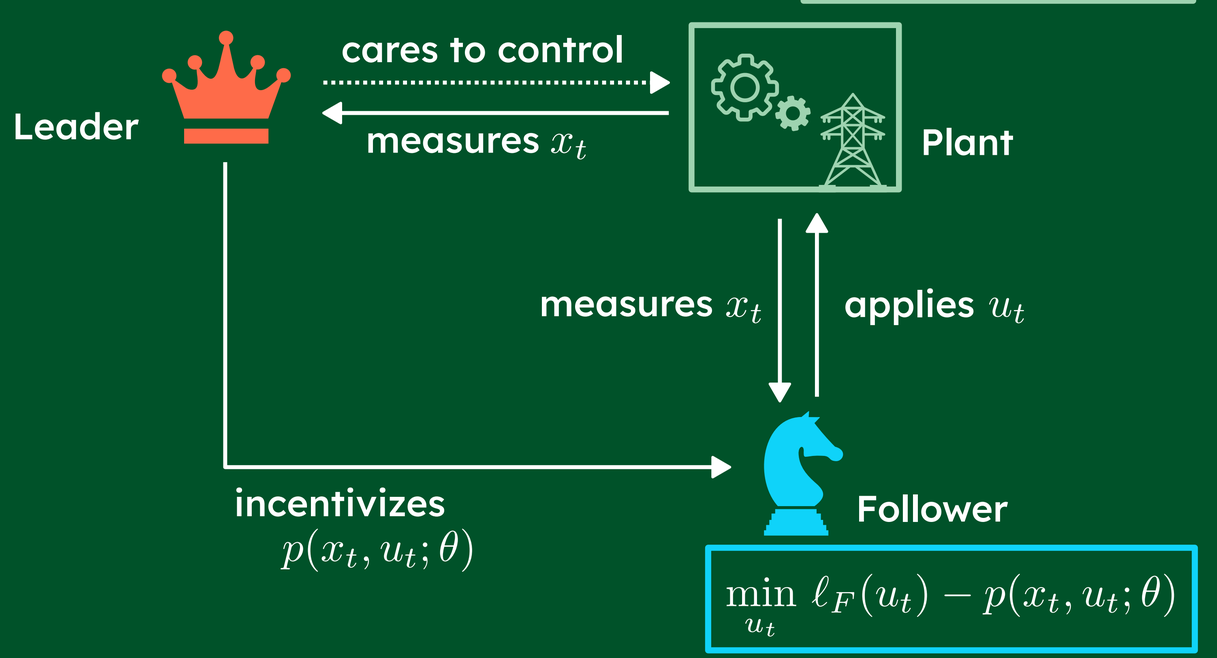
Procuring control services

? What if a leader seeks to control a plant, but relies on self-interested followers to provide the control inputs?

We model this problem as a dynamic Stackelberg game with an open-loop leader and a closed-loop follower.

$$\min_{\theta} \mathbb{E}\Big[\sum_{t=t_0}^{t_0+T-1} \ell_L(x_t) + p(x_t, u_t; \theta)\Big]$$

$$x_{t+1} = f(x_t, u_t, w_t)$$



A warm-up:
Linear-quadratic Gaussian with bilinear incentives

$$\min_{\theta} \mathbb{E}\Big[\sum_{t=t_0}^{t_0+T-1} x_t^2 + \theta x_t u_t\Big] \rightarrow p(x_t, u_t; \theta)$$

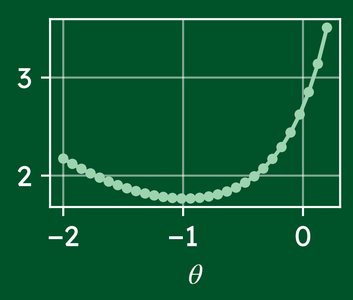
$$\text{s.t.} \begin{cases} \min_{u_t} \; c u_t^2 - \theta x_t u_t \\ x_{t+1} = a x_t + u_t + w_t \end{cases}$$

$$x_0 = 0, \quad w_t \sim \mathcal{N}(0, \sigma^2)$$

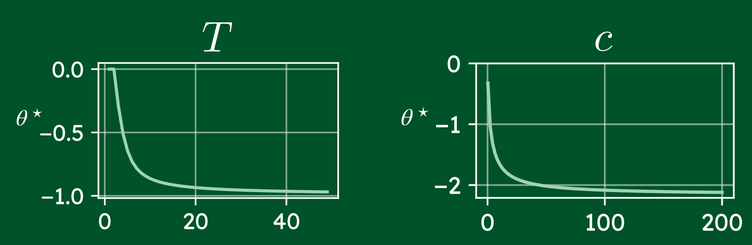
We can find an explicit solution for this simplified problem!

$$= (1 + \frac{\theta^2}{2c}) \frac{\sigma^2}{1 - \hat{a}^2} (T - \frac{\hat{a}^2(1 - \hat{a}^{2T})}{1 - \hat{a}^2})$$

$$\hat{a} := a + b/2c$$



The optimal leader decision has a global minimum and converges in all three problem parameters.



Jonas G. Matt, Florian Dörfler, Saverio Bolognani, Giuseppe Belgioioso

MAESTRO · Automatic Control Laboratory IFA · National Centre of Competence in Research Automation