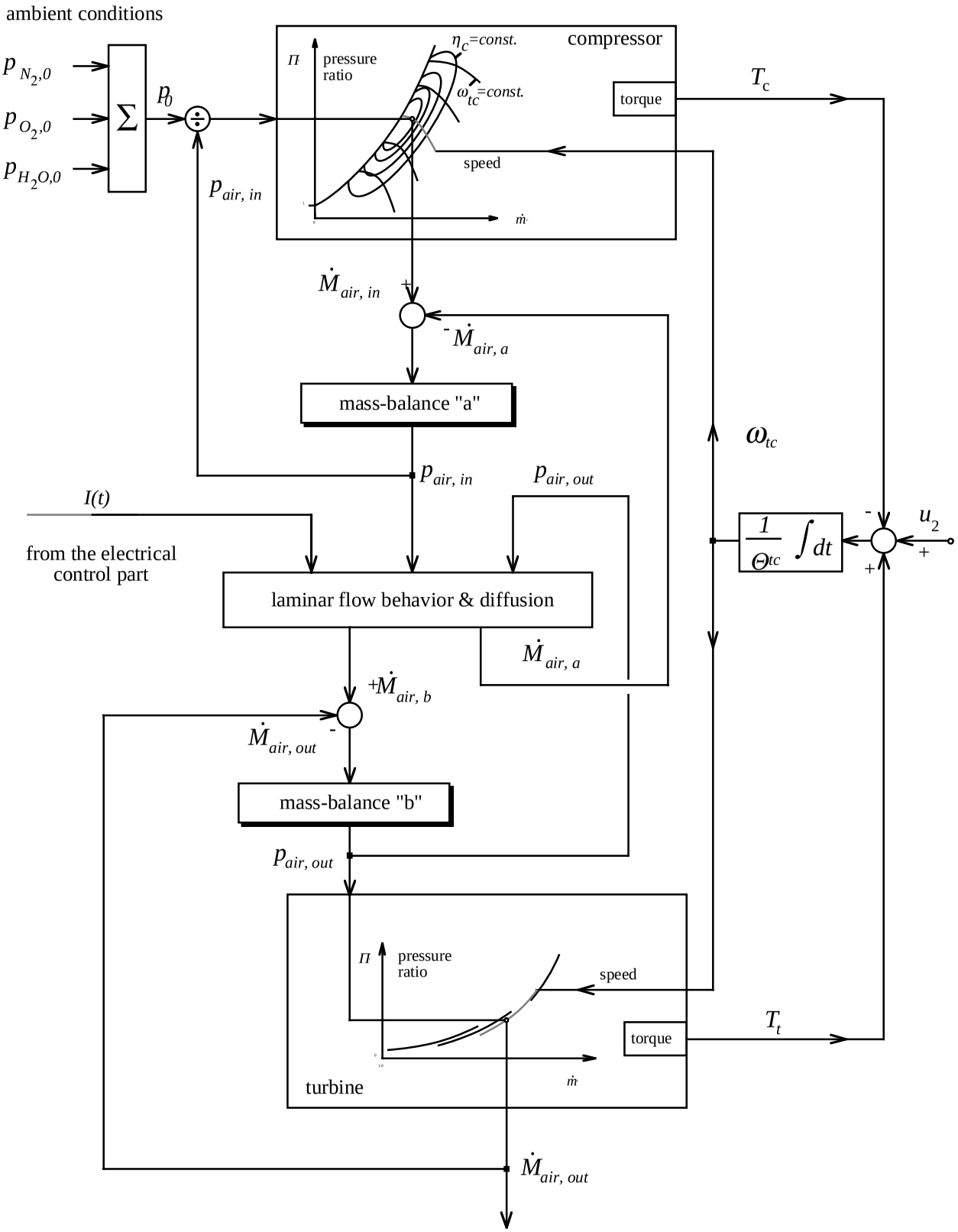

ambient conditions
$p_{N_2,0}$
$p_{O_2,0}$
$p_{H_2O,0}$
$\Sigma$
$p_0$
÷
$p_{air,\,in}$
$\Pi$
pressure ratio
$\eta_c$=const.
$\omega_{tc}$=const.
compressor
torque
$T_c$
speed
$\dot{m}$
$\dot{M}_{air,\,in}$
+
-
$\dot{M}_{air,\,a}$
mass-balance "a"
$\omega_{tc}$
$p_{air,\,in}$
$p_{air,\,out}$
$I(t)$
from the electrical control part
$\frac{1}{\Theta tc}\int dt$
$u_2$
laminar flow behavior & diffusion
$\dot{M}_{air,\,a}$
$+\dot{M}_{air,\,b}$
$\dot{M}_{air,\,out}$
mass-balance "b"
$p_{air,\,out}$
$\Pi$
pressure ratio
speed
$T_t$
torque
turbine
$\dot{m}$
$\dot{M}_{air,\,out}$

# Modeling and Control of FC Systems

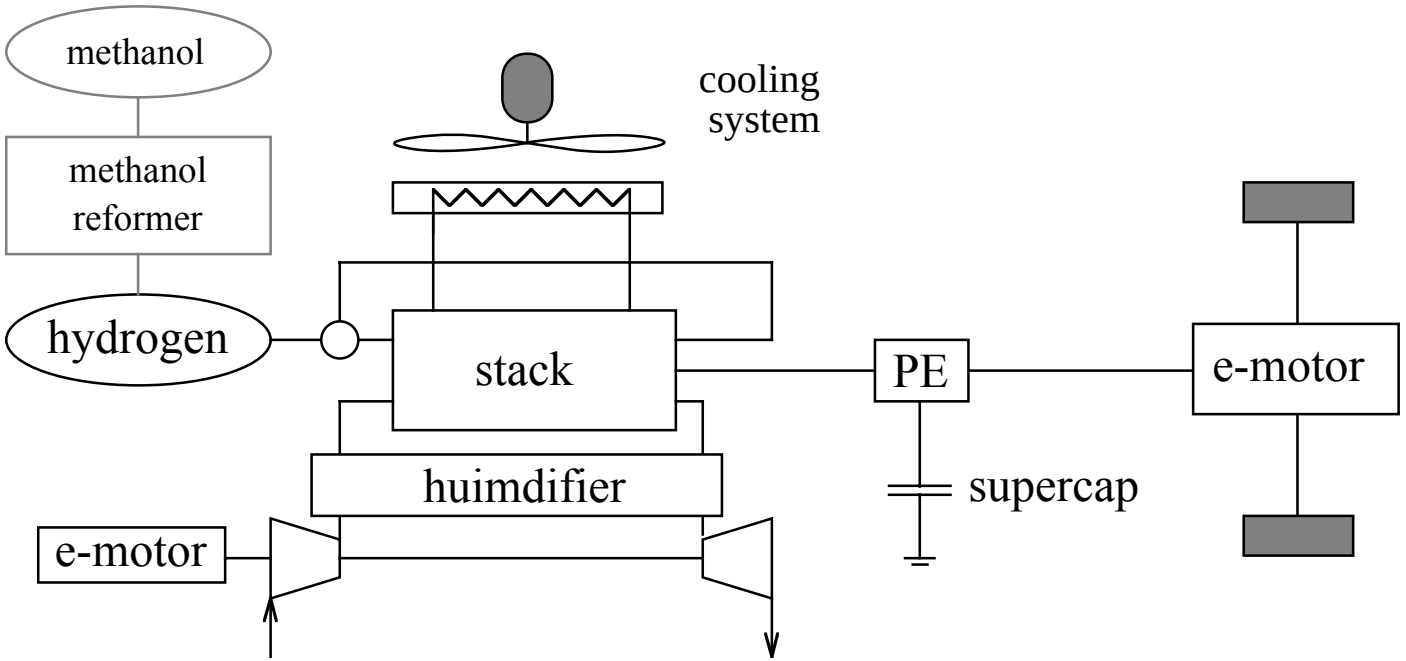
*Control tasks*

- Maintain desired mass-flows (load control)
- Keep absolute pressure in cell at (changing) level (power density, load control)
- Maintain desired Air/Fuel-ratios (efficiency)

- Keep pressure differences over the membrane at desired level (max limited)
- Keep pressure differences over the cell in desired range (blow-out of water)
- Keep membrane at desired humidity
- Keep membrane at desired temperature

# Modeling and control of FC based powertrains

## *Vehicle system*



*Some general remarks*

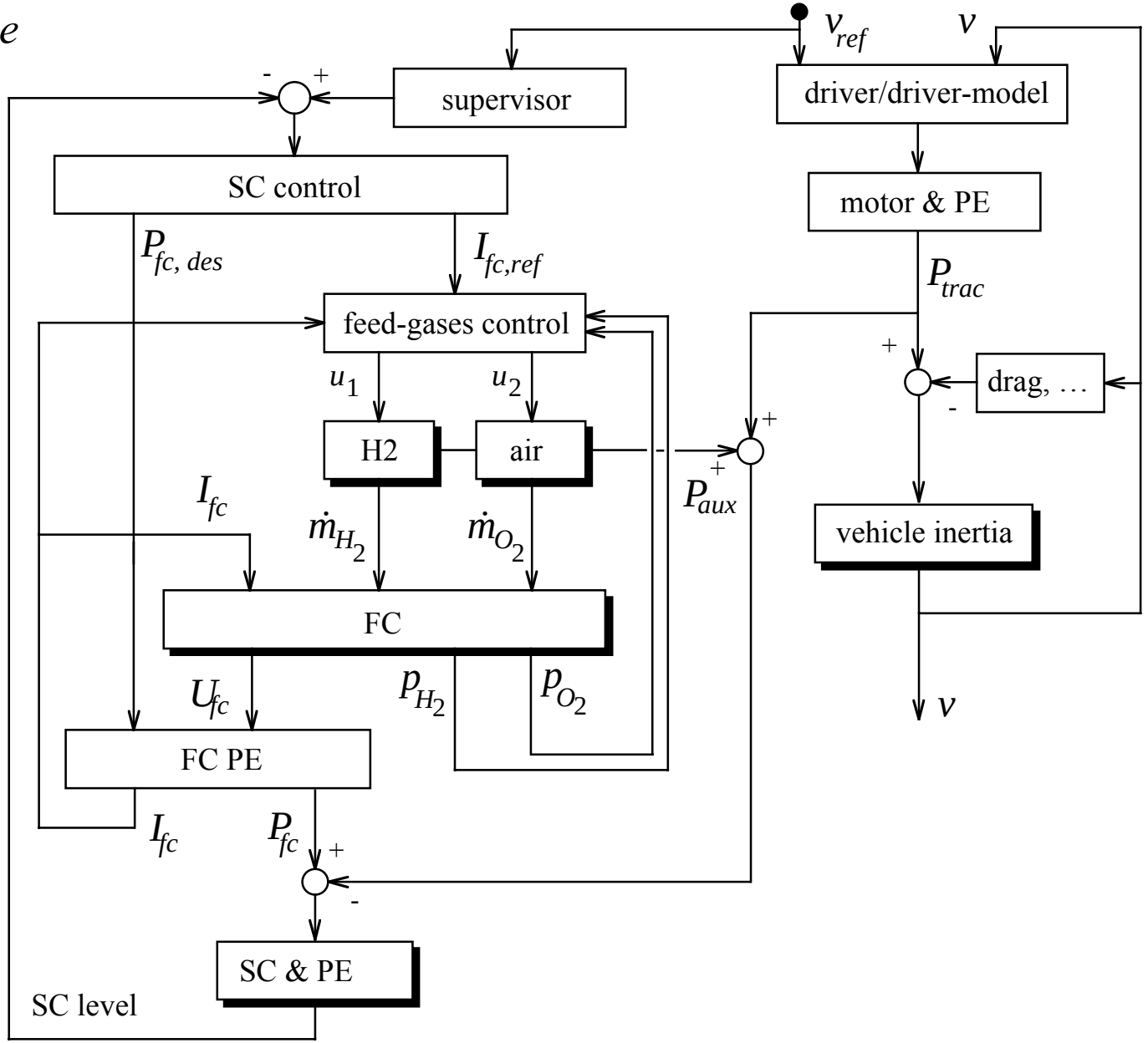
- Fuel-cell vehicles have many similarities wirh hybrid vehicles
- Several power sources and energy storages have to be coordinated for comfort performance, fuel-economy, ……
- A Super-Cap is usually needed for acceleration and braking energy recuperation; SC offer the main "degree-of-freedom" in the control algorithms
- At least two levels of control action:

  > supervisory level (load distribution, optimal device scheduling …)

  > component level (driver's torque demands, fuel-cell operation, …)

- Different optimization "horizons" possible (local or global, single or multiple vehicles, …)

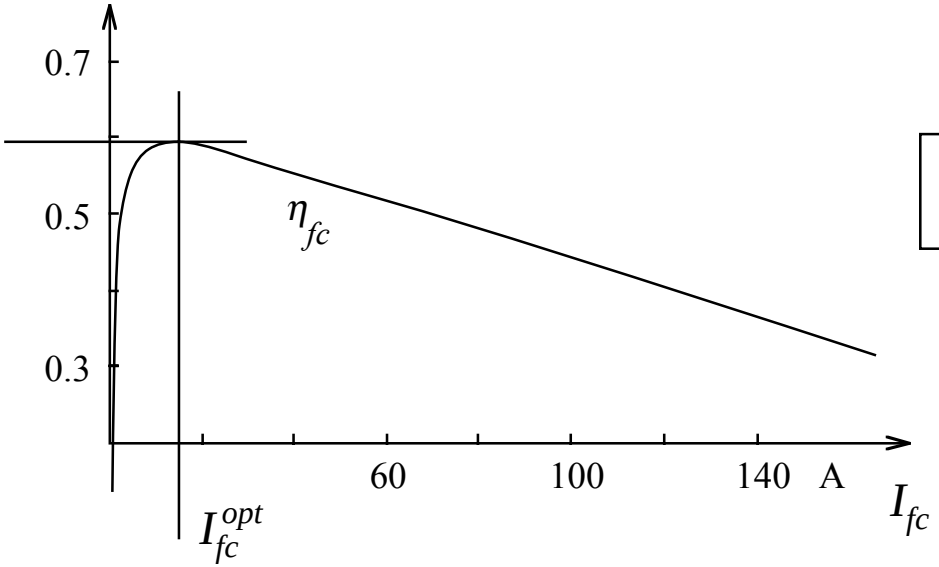
*System structure*

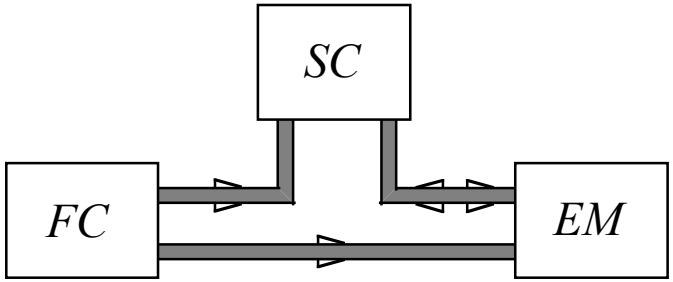


## *Strategy#1: "short" time-horizon*

- For currents larger than $I_{fc}^{opt}$ feed EM dirctly from FC as much as possible and use SC as a reserve for accelerations/decelerations, only.

- If current smaller than $I_{fc}^{opt}$ check if gain in efficiency in FC is larger than the corresponding losses (≈ 20%) when using the SC in a duty-cycle mode.

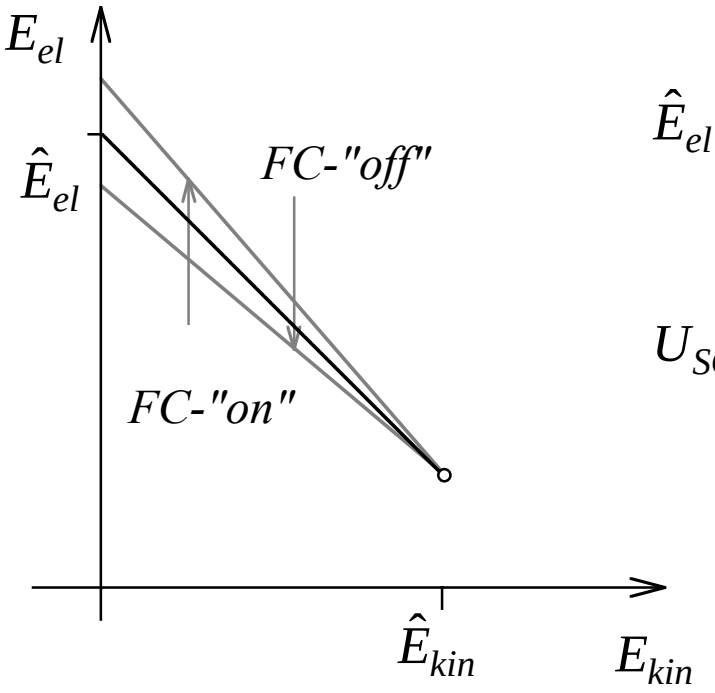


## *Strategy #2: "long" time-horizon*

- Keep total system energy (kinetic and electric) at constant level such that there is at low speeds sufficient energy to accelerate (say 0 to 60 mph) and at high speeds sufficient capacity to store the recuperated energy when braking

- SC may not be depleted completely (e.g. 1/4th of the max. energy is the lower limit)




$$\hat{E}_{el} = \frac{4}{3} \cdot \hat{E}_{kin}$$

$$U_{SC,nom}(v) = \sqrt{\frac{m_{veh}}{C_{SC}}(\hat{v}_{veh}^2 - v_{veh}^2) + \frac{1}{4}\hat{U}_{SC}^2}$$

*Summary*

- FC and FC based vehicles pose many "classical" control problems
- The "electrochemistry" is fast and can be modelled as a nonlinear algebraic relation
- FC based vehicles have many similarities with hybrid vehicles, several levels of controls (torque and driveability, supervisory, path-planning, etc.) can be addressed
- A high-power density buffer is needed (usually SC) for driveability; this element offers also opportunities for fuel economy improvements