STATE OF CHARGE CONTROL FOR RENEWABLE ENERGY FED MICROGRIDS

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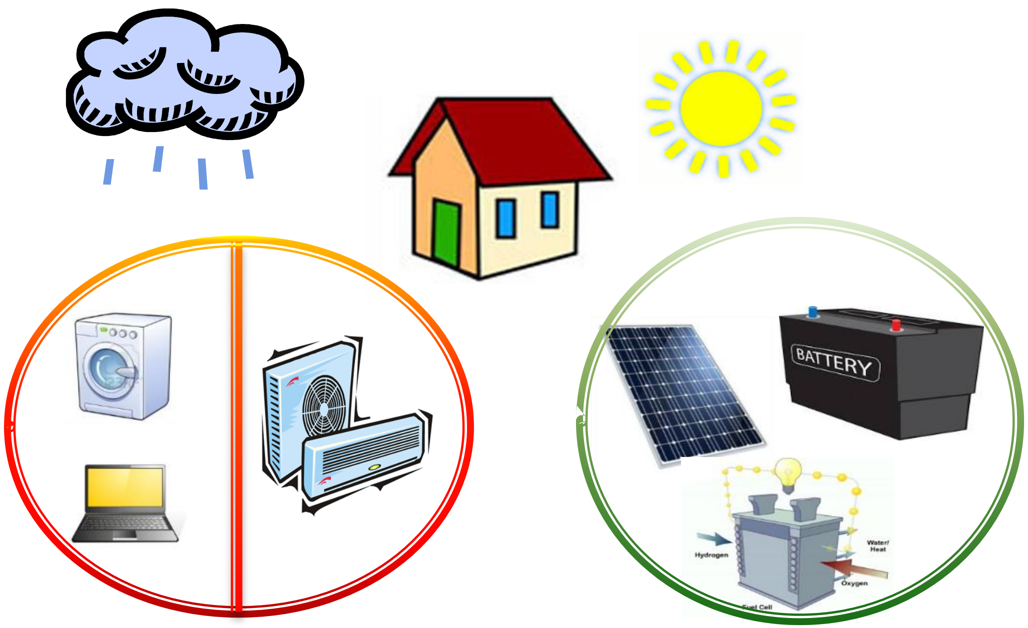
Research field | Distributed generation

Domestic micro-grid



Energy load

Energy source

OBJECTIVE:
- Exploit as much as possible renewable energy
- Reduce cost

CONSTRAIN
- Maintain Comfort

both depend on unknown ambient condition.

Predictive Control System (Model Predictive Control)

RBC & MPC | Pros & cons

BASELINE MICROGRID CONTROL STRATEGY

RBC

RULED BASED CONTROL

- Current state
- Start/stop Fuel Cell & HVCA
- If condition

Expect:

- *HIGH variability operating conditions*
- *Not optimal fuel cell use*

VS

ADVANCED MICROGRID CONTROL STRATEGY

MPC

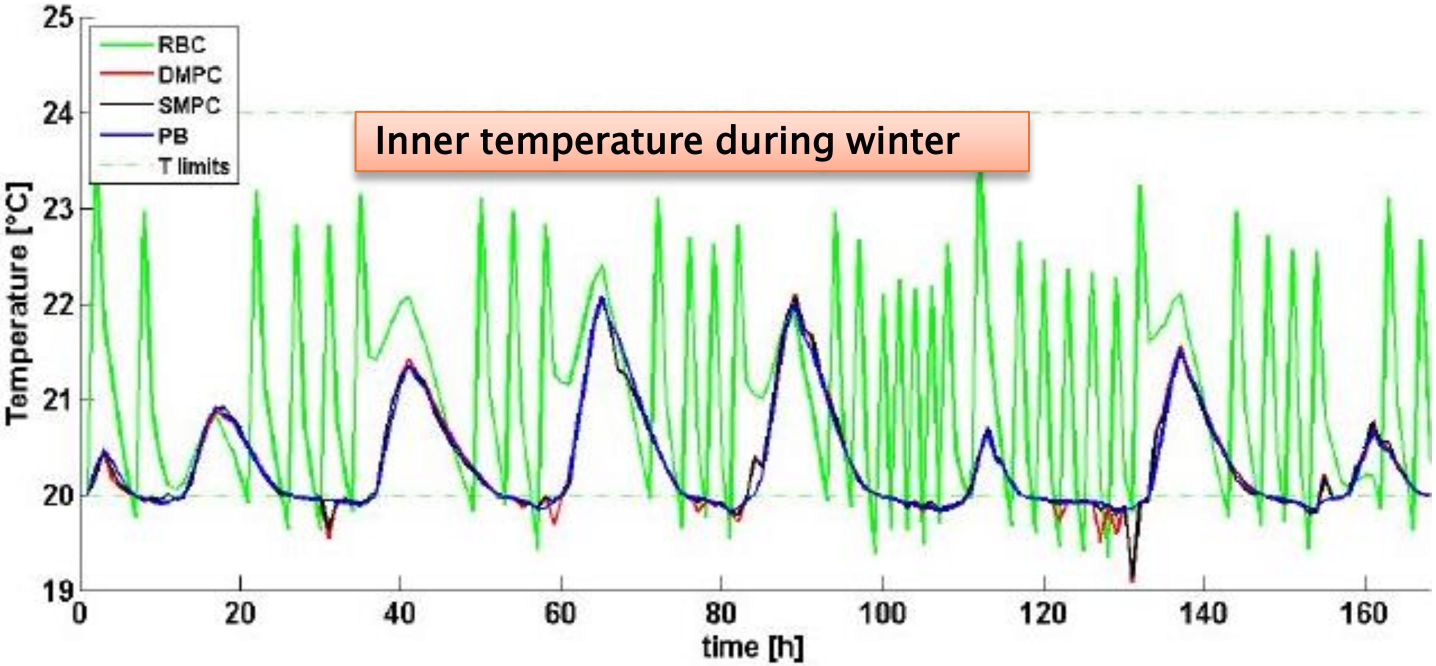
MODEL PREDICTIVE CONTROL

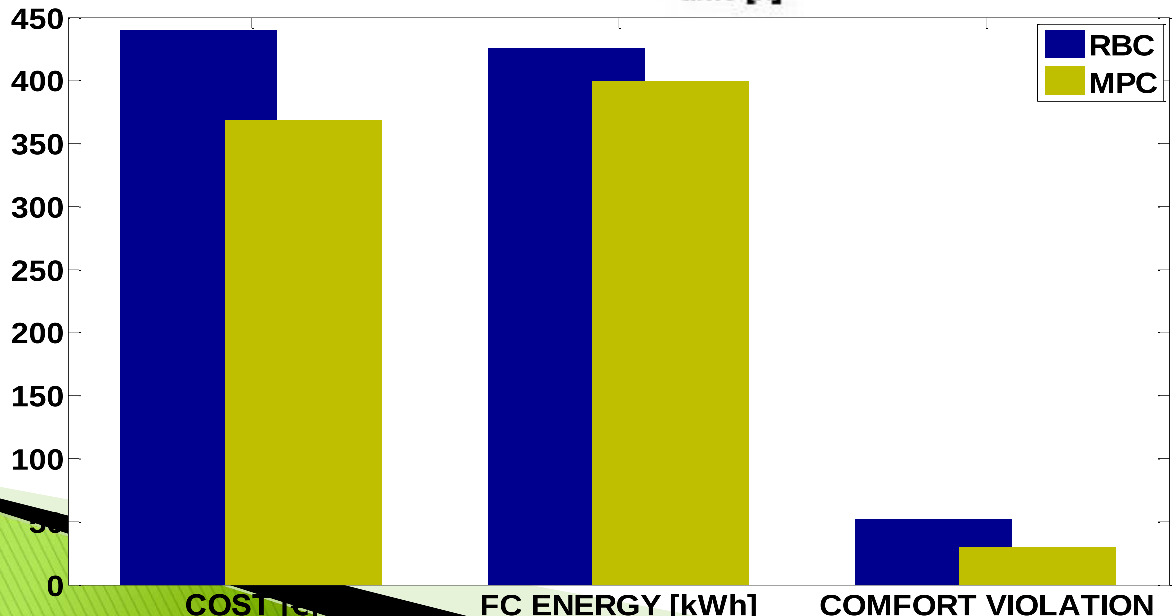
- Past, present, future state: Use weather forecast
- Control Fuel Cell & HVCA at PARTIAL LOAD
- Need a system model & Optimization algorithm

Expect:

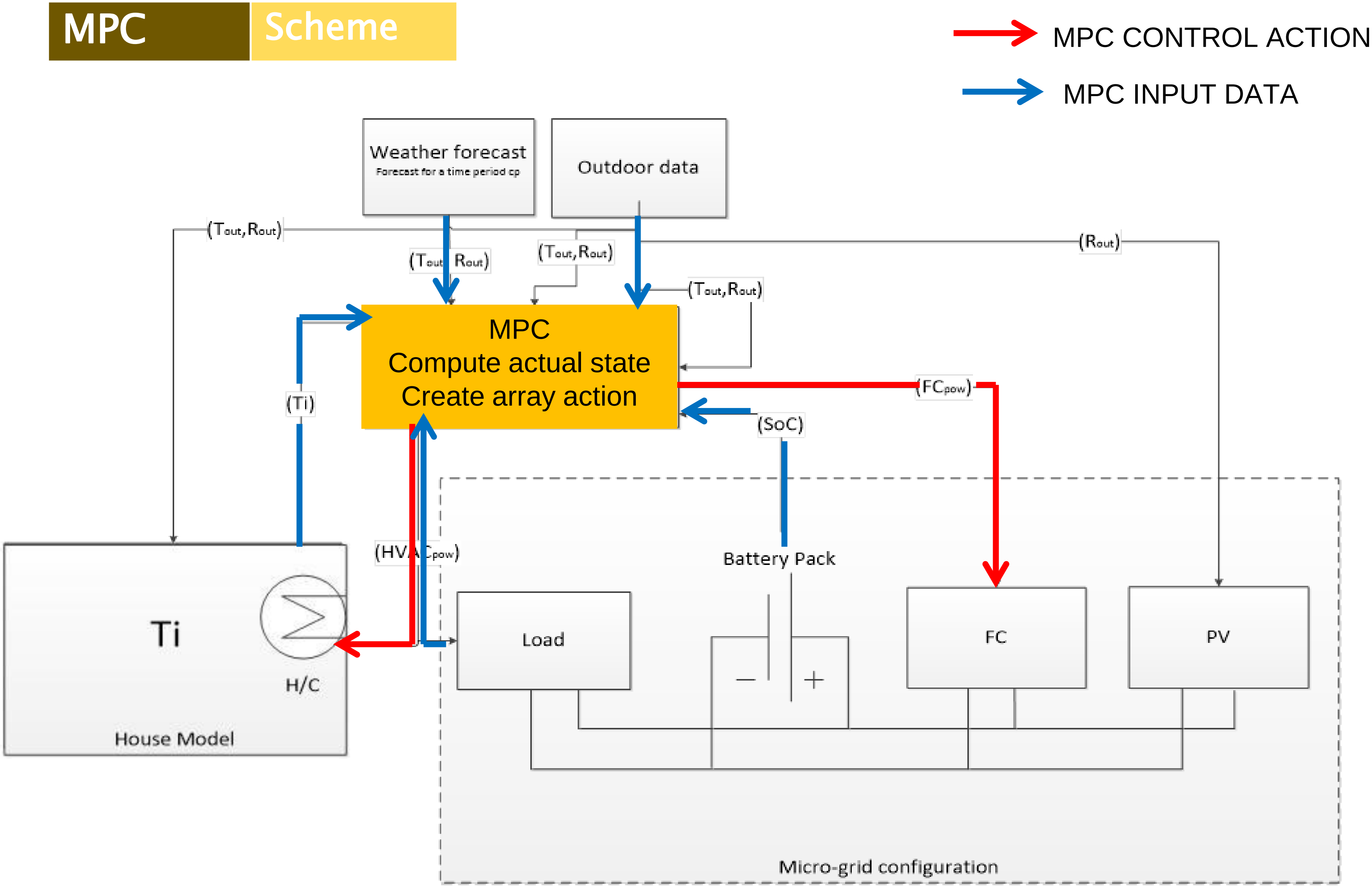
- *SOFT variability operating conditions*
- *High efficiency*

RBC & MPC SIMULATION RESULTS



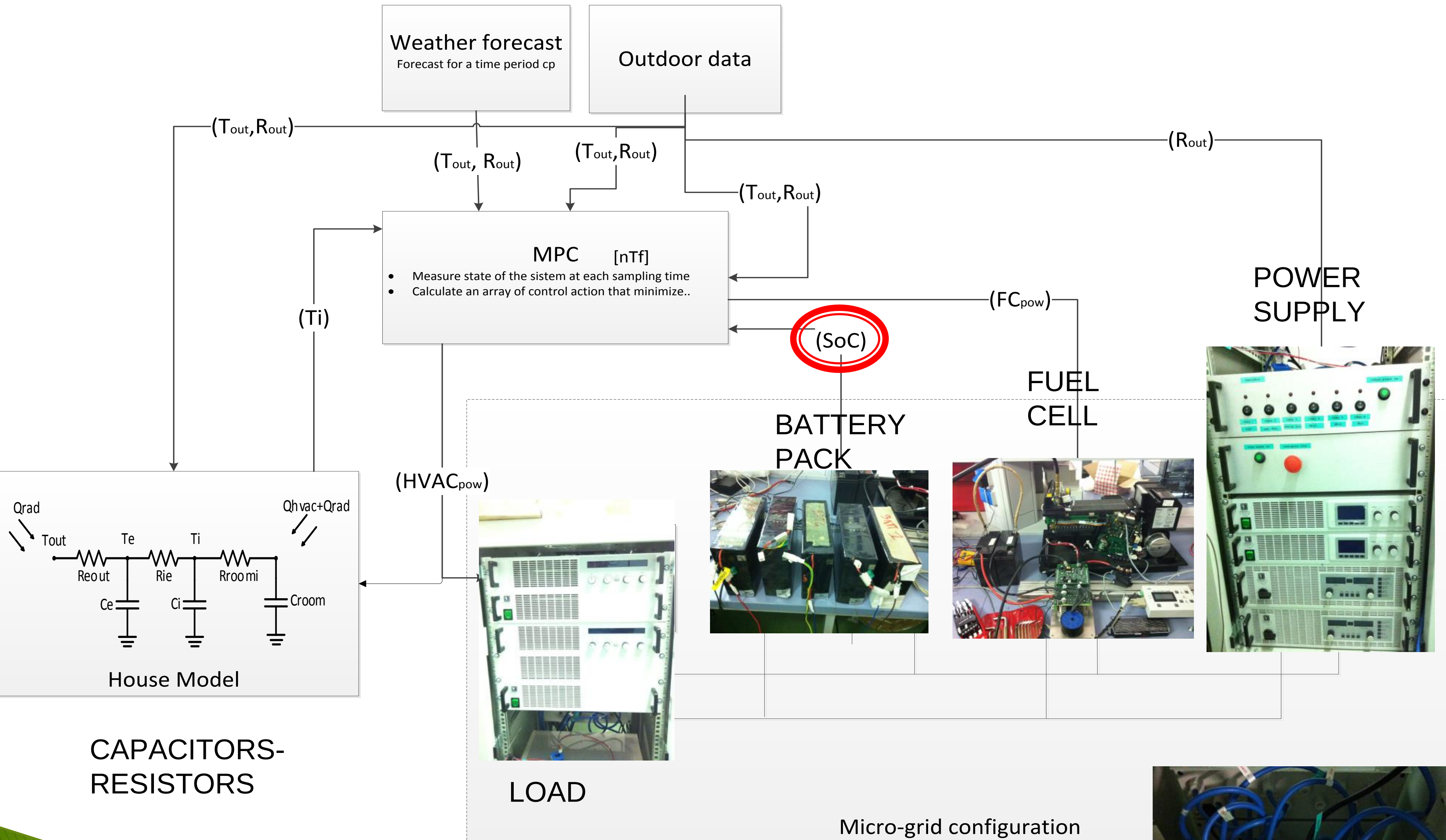


MPC Scheme



MPC CONTROL ACTION
MPC INPUT DATA
Weather forecast
Forecast for a time period cp
Outdoor data
(Tout,Rout)
(Tout,Rout)
(Tout,Rout)
(Rout)
(Tout,Rout)
MPC
Compute actual state
Create array action
(Ti)
(FCpow)
(SoC)
(HVACpow)
Battery Pack
Ti
H/C
House Model
Load
FC
PV
Micro-grid configuration

MPC EXPERIMENTAL SET UP

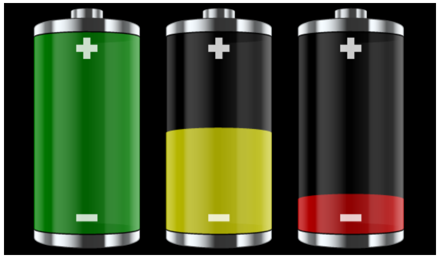


$$State\ of\ Charge = \frac{CHARGE\ still\ available\ for\ discharge}{MAXIMUM\ CHARGE}$$

DC BUS

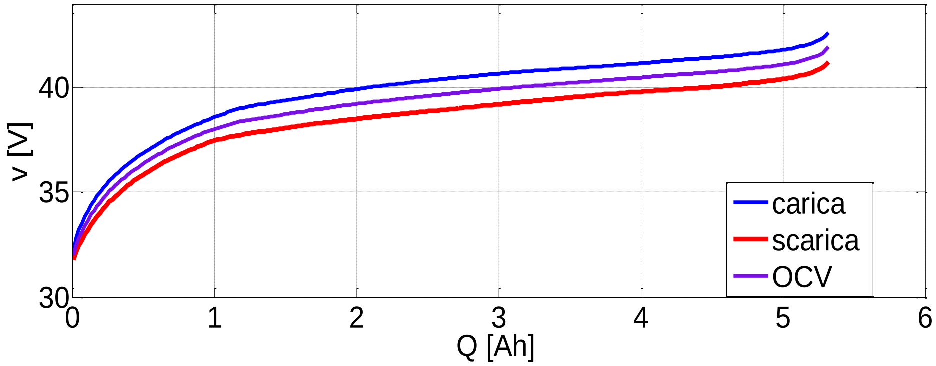
PERSONAL OBJECTIVE

Determine the **State of Charge** (SoC)



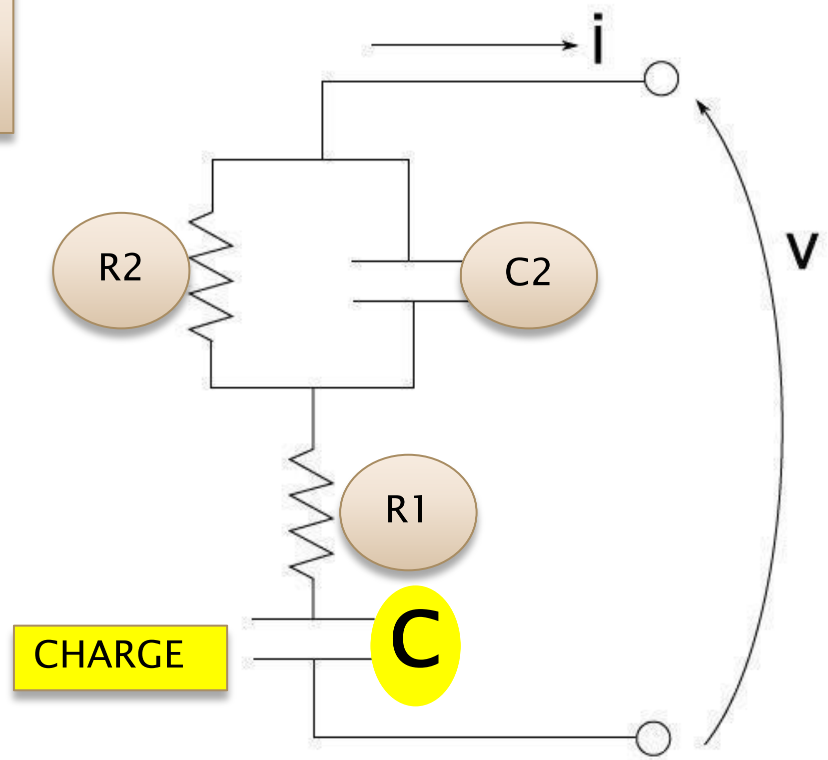
1. PROPORTIONAL to OCV.
2. OCV cannot be directly measured, if system is working.
3. Other measure: CURRENT – CCV (close circuit voltage)
4. Also them have measuring errors

...so, let's see how to proceed!



ELECTRIC CIRCUITAL MODEL

Simplified model:
CONSTANT
PARAMETERS



CIRCUIT EQUATIONS

$$\begin{cases} \dot{v}_C = -\frac{1}{C} i \\ \dot{v}_{C_2} = -\frac{1}{R_2 C_2} v_{C_2} - \frac{1}{C_2} i \\ v = f_{OCV}(v_C) + v_{C_2} - R_1 i \end{cases}$$

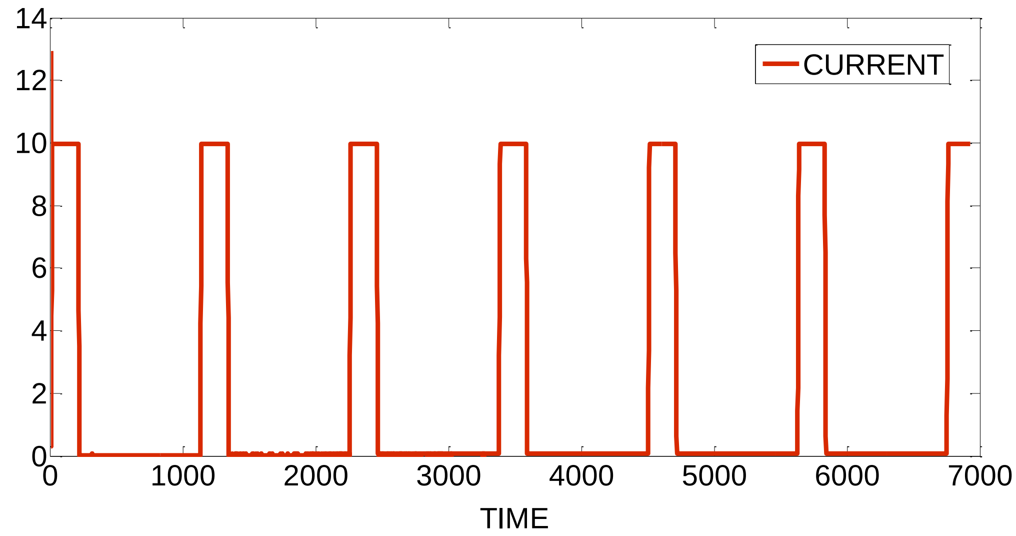
Need to calculate R1 R2 and C2

SoC evaluation | Battery characterization

DYNAMICS DISCHARGE TEST:

- Current step
- Relaxation time
- Acquire data (Labview)
- Post process (Matlab)

IMPULSE CURRENT REQUEST load



ALGEBRIC STEPS:

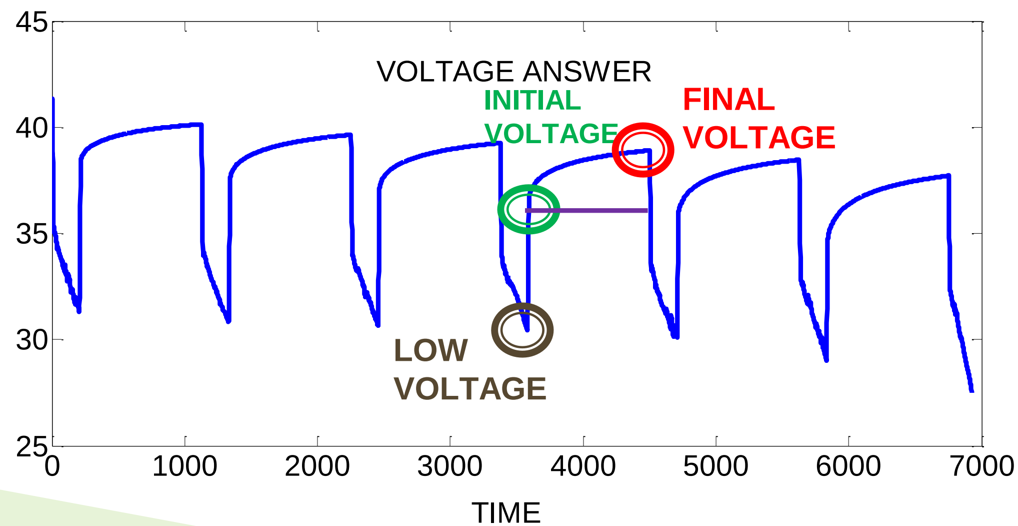
$$R1 = \frac{V_{INITIAL} - V_{LOW}}{CURRENT}$$

$$Rint = \frac{V_{FINAL} - V_{LOW}}{CURRENT}$$

$$R2 = Rint - R1$$

$$C2 = tau / R2$$

VOLTAGE ANSWER MEASURED



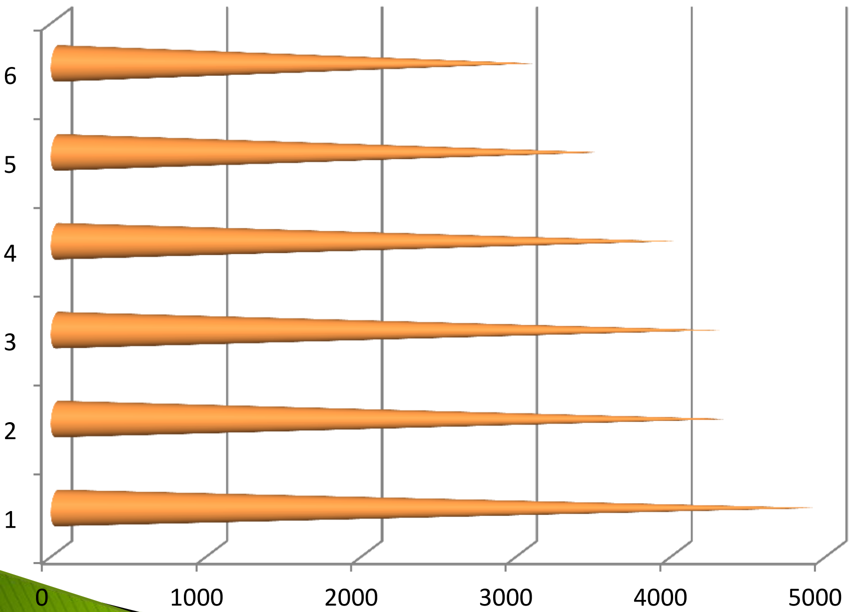
Resistances

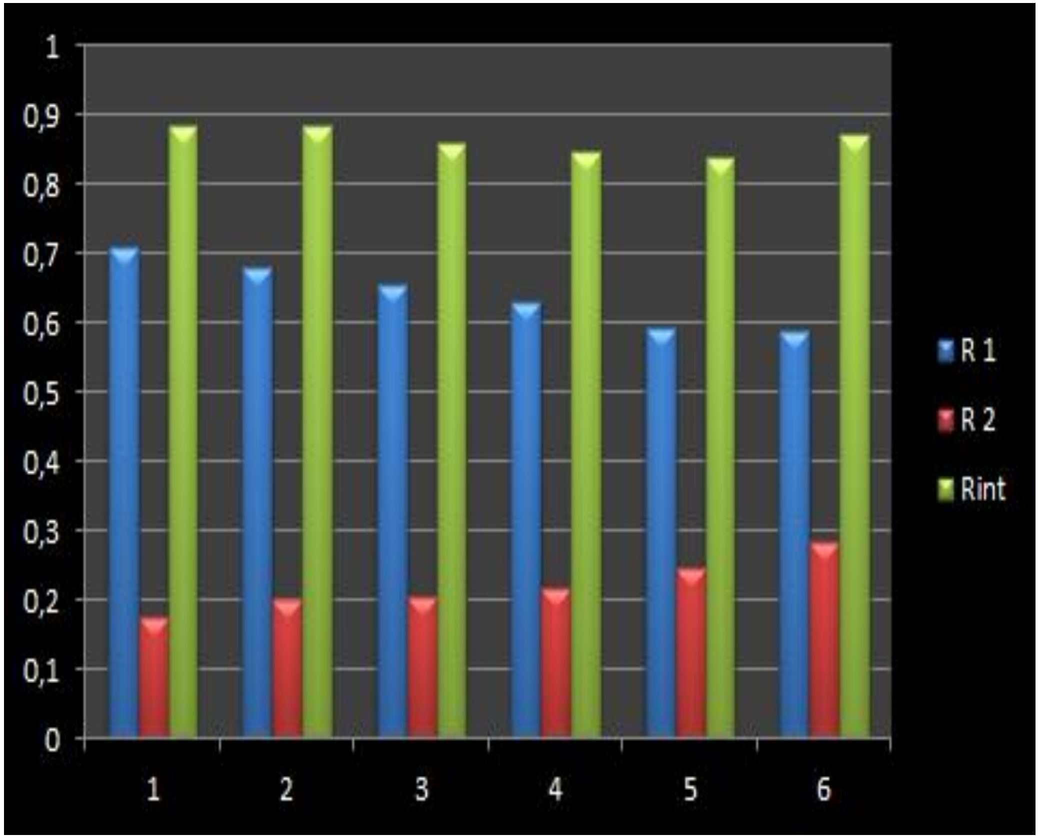
Average values

R1	R2	Rint
0,642 Ω	0,221 Ω	0,863 Ω

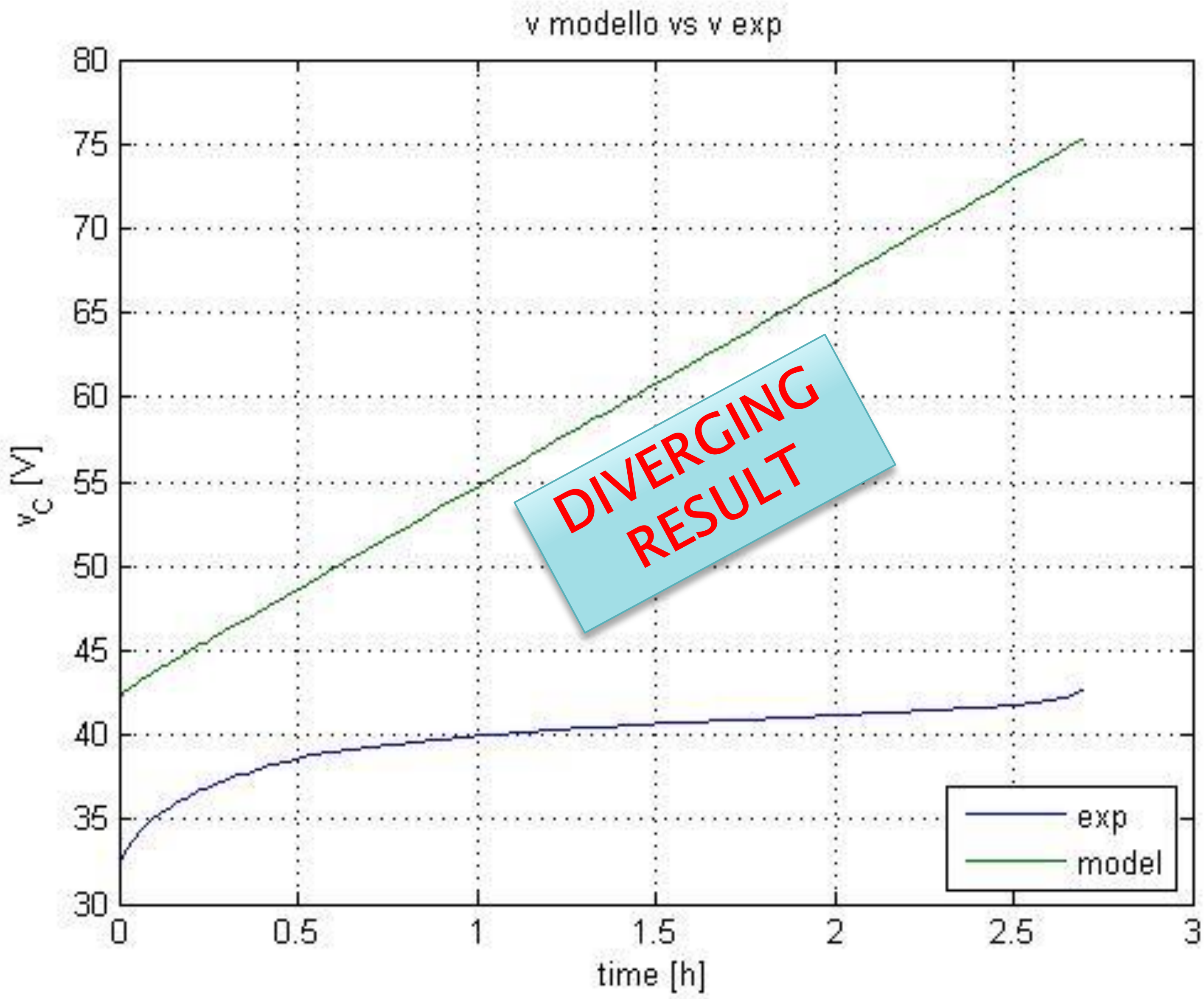
Capacitances

Average value C2:
4030 C



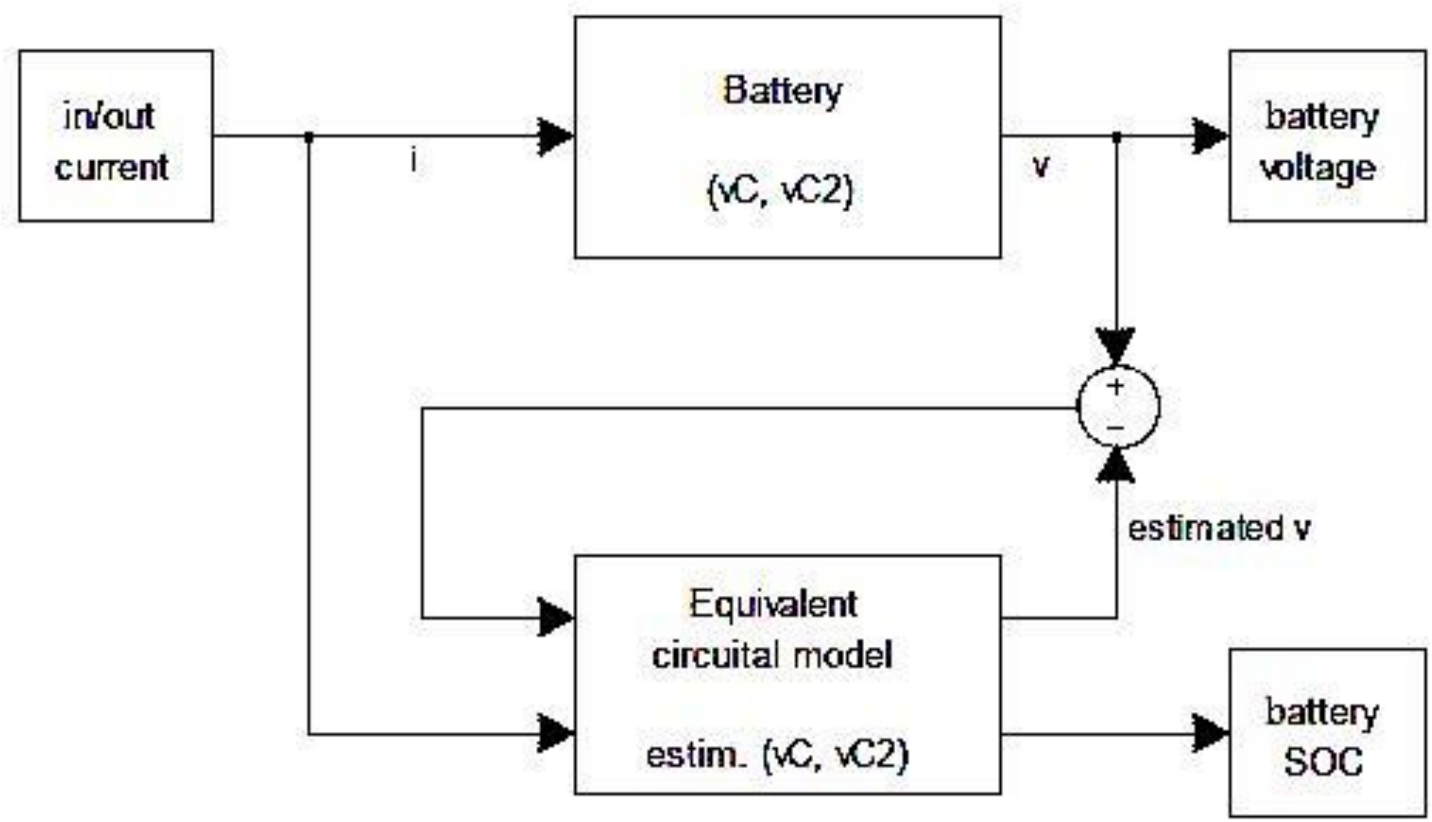


SoC evaluation | Initialization error



SoC evaluation | STATE OBSERVER

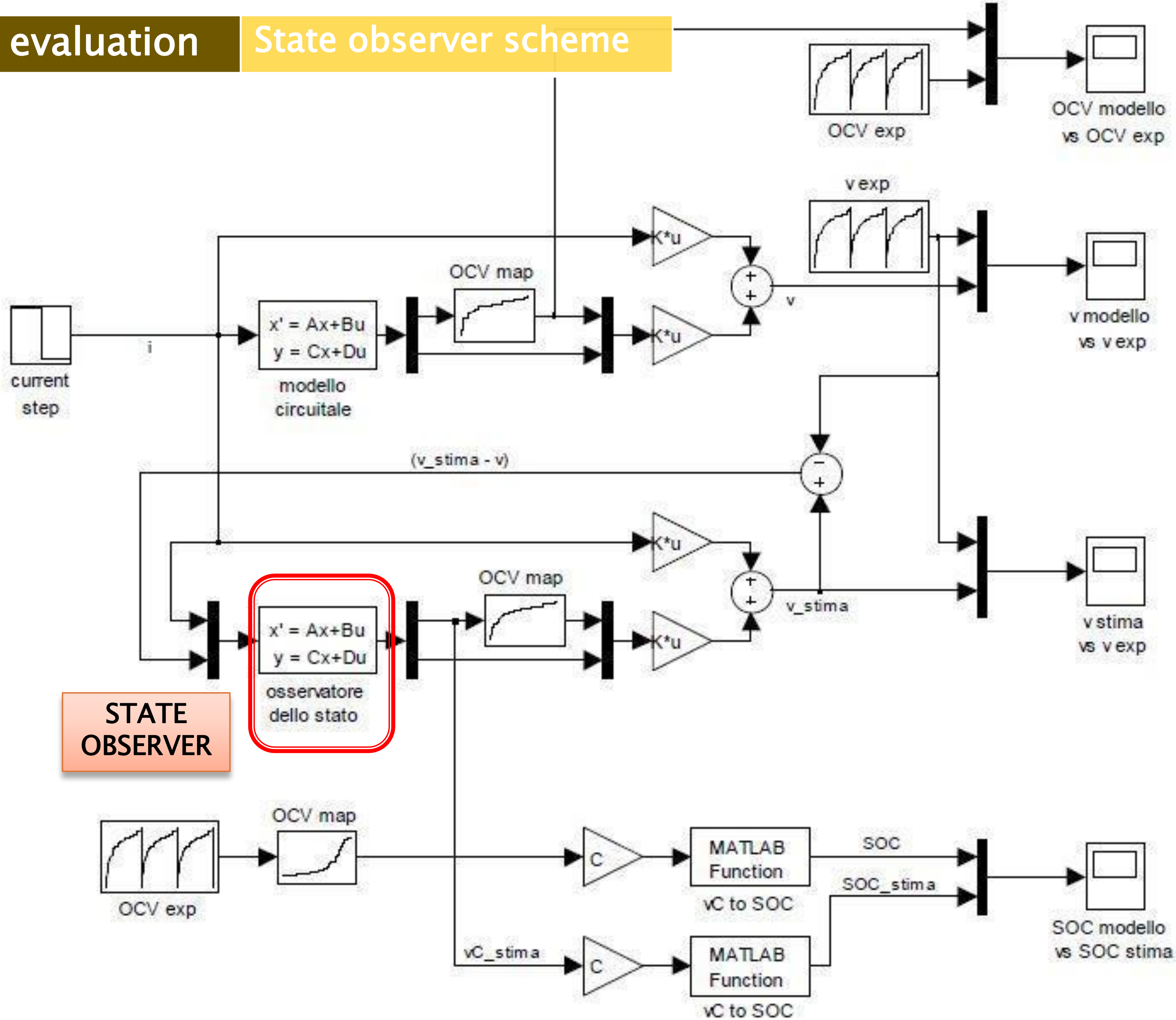
TO AVOID ERROR PROPAGATION → CLOSED LOOP CONTROL



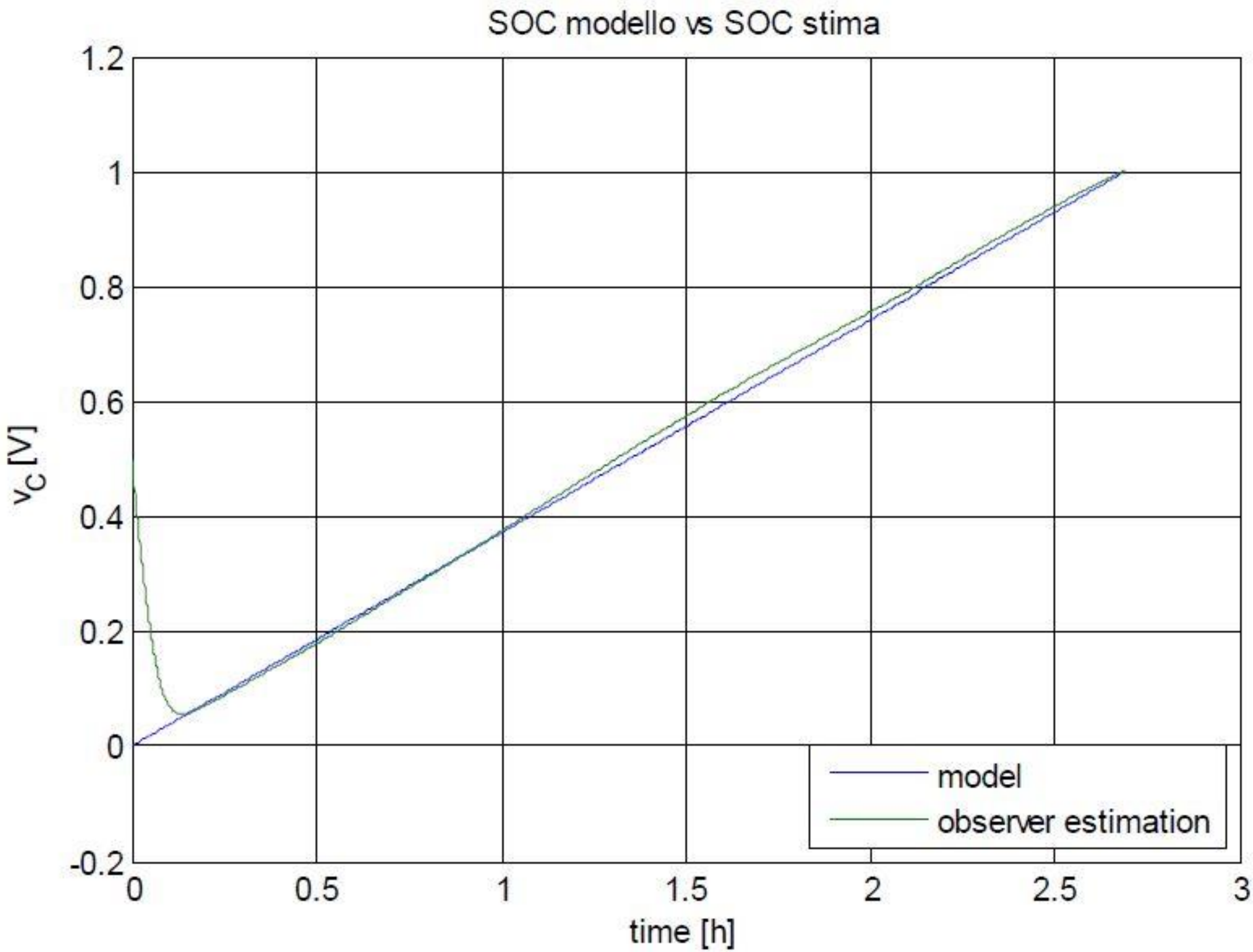
$$\dot{\hat{v}}_C = -\frac{1}{C} i - k_1 (v - \hat{v})$$

$$\dot{\hat{v}}_{C_2} = \frac{1}{R_2 C_2} \hat{v}_{C_2} - \frac{1}{C_2} i - k_2 (v - \hat{v})$$

SoC evaluation | State observer scheme



SoC evaluation — State observer result



Conclusions

- MPC better than RBC
- Key role: SoC measurement
- A simple but accurate model, to measure SoC has been presented
- Results are encouraging as SOC measurement capabilities have been demonstrated