# Battery Parameter Estimation

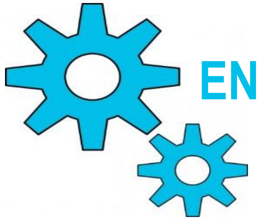


**Presented by**
**Shanmugam,Thayalan**
**Udayakumar, Praveenkumar**

RENAULT · NISSAN
JOINT VENTURE COMPANY

# RNTBCI – Brief Introduction

- Based in Chennai, India
- Established in 2007
- More than 6,300 employees
- R-N's only Alliance R&D center
- Competitive alliance center

**ENGINEERING**

- Product Engineering
- Production Engineering
- Research and Advanced Engineering

**IS/IT**

- Information System/ Information Technology

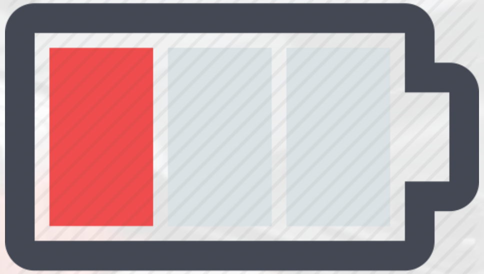
# CONTENTS

# OBJECTIVE BATTERY MODELING

Battery performance depends on,

Environment conditions and operating factors

- Aging
- SOC
- Temperature

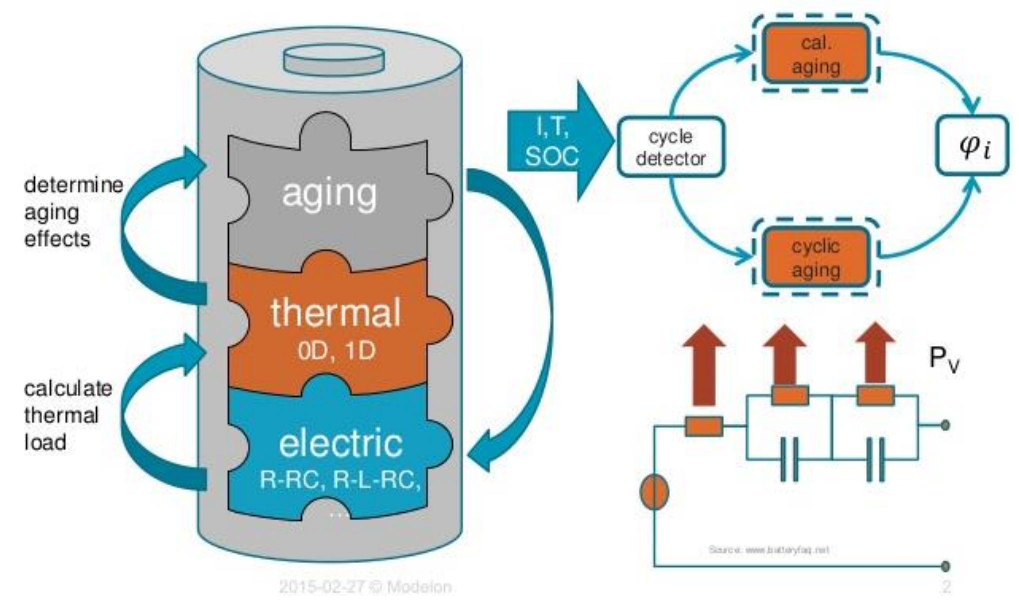


## Factors that influence the capacity

- Rate of charge and discharge
- Temperature
- Self discharge (internal resistance)
- Cycle number
- Over charge

## Proper battery model is needed

- Robust testing of BMS at HIL.
- Developing Proper controlling algorithm (ASW).
- Analyzing battery performance w.r.t different chemistry
- To prevent accelerated aging effect

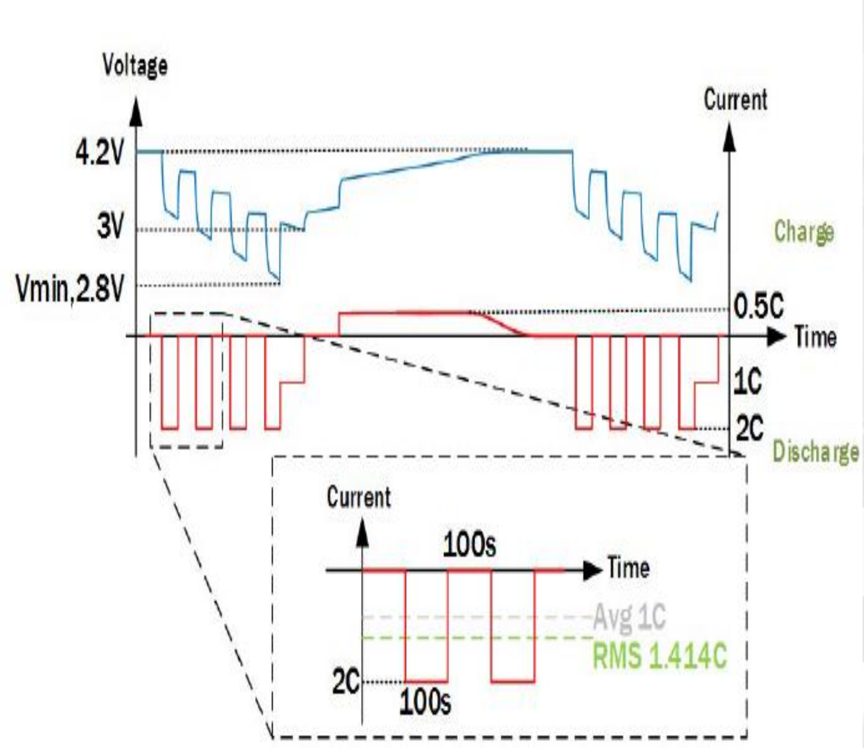


# BATTERY TESTING

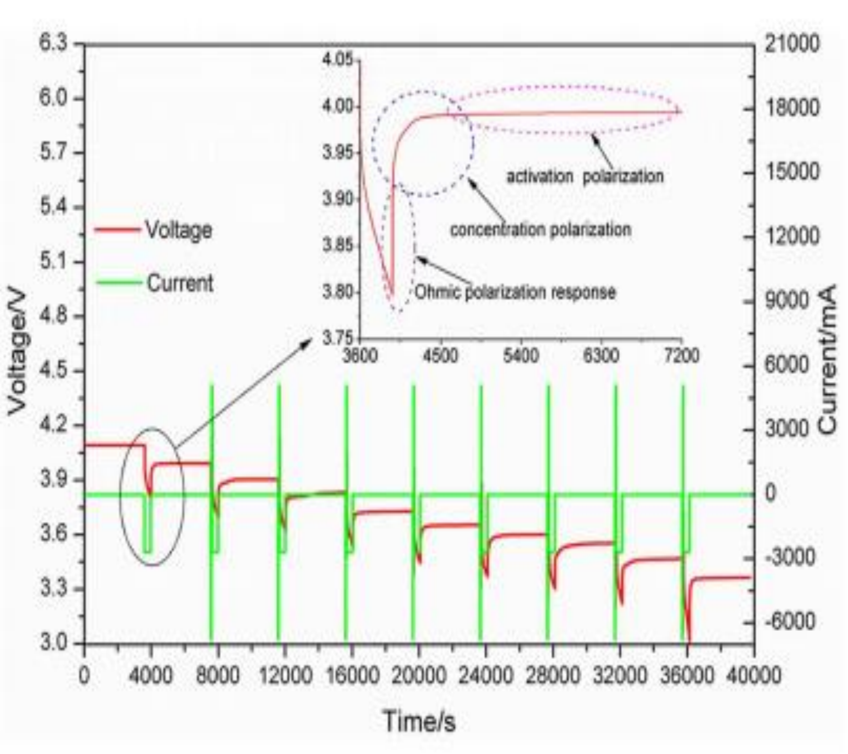
To check the aging effect, degradation and state of health

Batteries under go some current tests

- Pulse Current Discharge
- Hybrid Pulse Power Characterization
- Static Capacity
- Self Discharge
- Energy Efficiency
- Cold Cranking




Pulse Current Discharge Test




Hybrid Pulse Power Characterization Test

# BATTERY MODEL


Batteries

- Non linear Systems

**Real-time determination of the parameter is challenging**

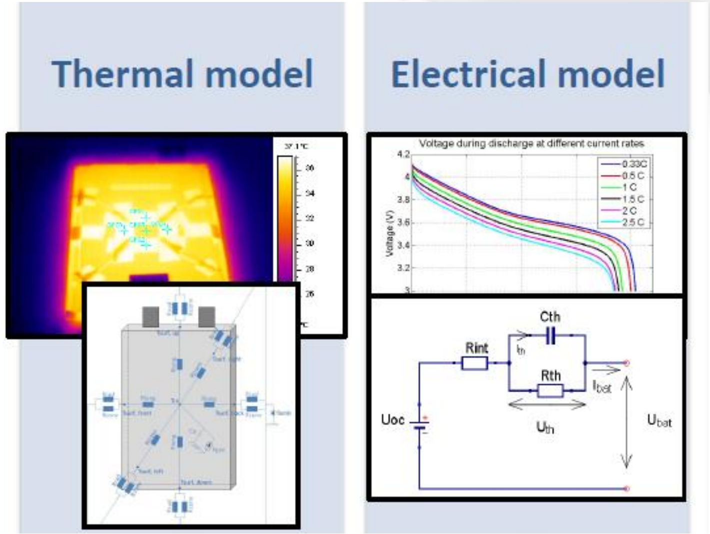

## DIFFERENT TYPES OF MODELS

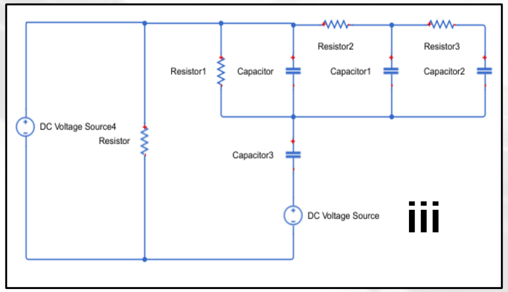
- ✓ Electrical models
- ▪Thermal models
- ▪Electrochemical models
- ▪Interdisciplinary models(electro – thermal)

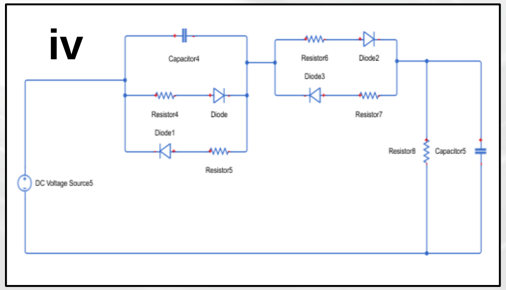
## EQUIVALENT CIRCUIT BASED MODELS

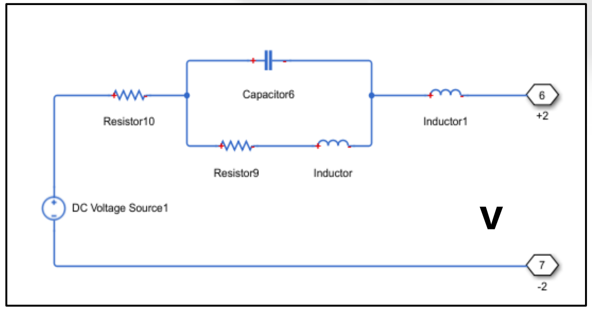
i. Thevenin equivalent model
ii. First, second and third order model
iii. Linear electric model
iv. Non-linear electrical model
v. Impedance based models

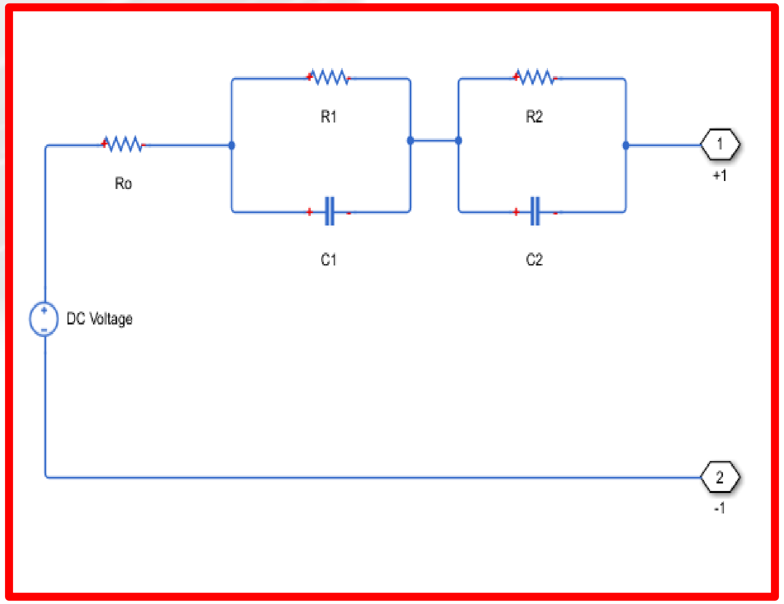
**Second order model is used**



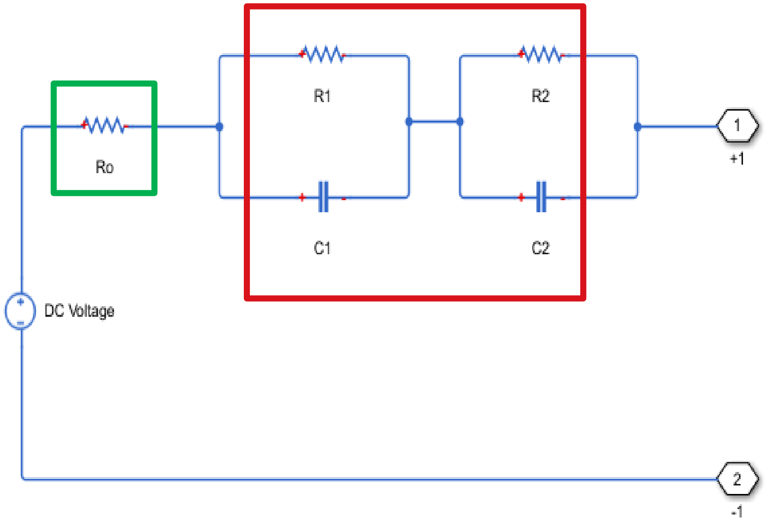



# What are parameters?

## How does parameters effect in battery voltage?

**Instantaneous Response**
*Due to ohmic effects*

**Delayed Response**




**Internal Resistance**

$$R_0 = \frac{V_0}{I_{discharge}}$$

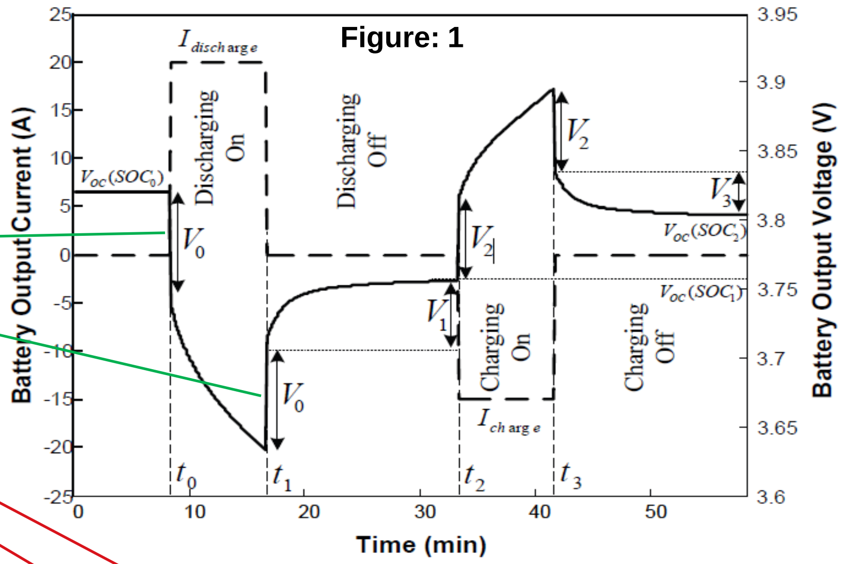
**Parallel Resistance**

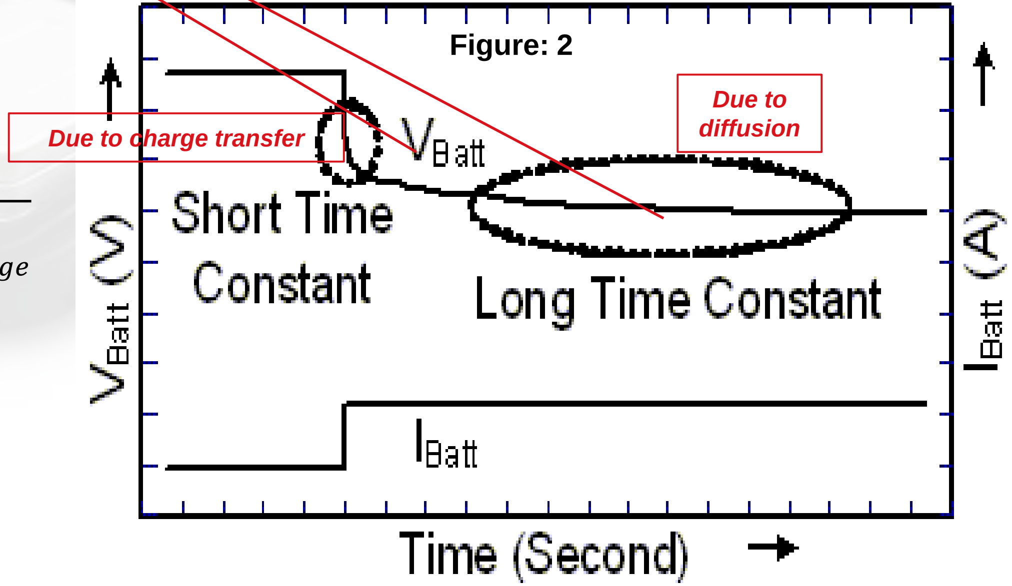
$$R_1 = \frac{V_2(t_3)}{\left(1 - e^{\frac{-T_{charge}}{\tau}}\right) * I_{charge}}$$

$$\tau = RC$$

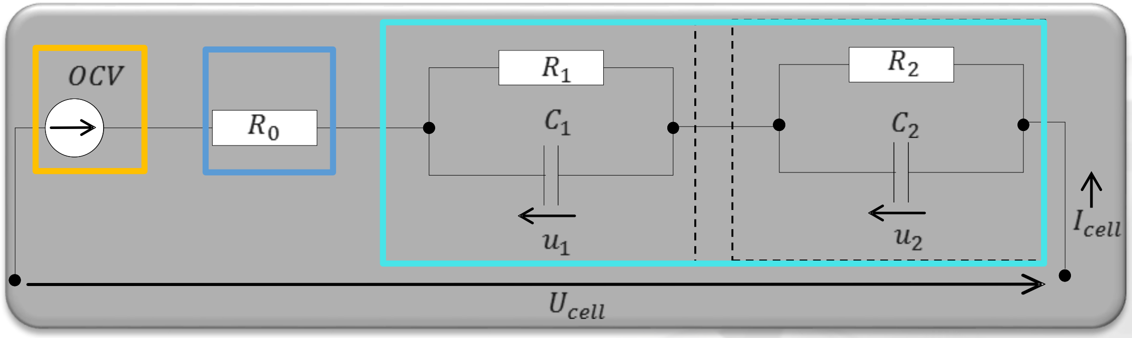
**Parallel Capacitance**

$$C_1 = \frac{\tau}{R_1}$$



# Ucell representation using 2 RC




HPPC data

Open Circuit Voltage

Voltage due to Internal Resistance

Characteristics remaining

*Settling time($t_{set}$) of RC network*

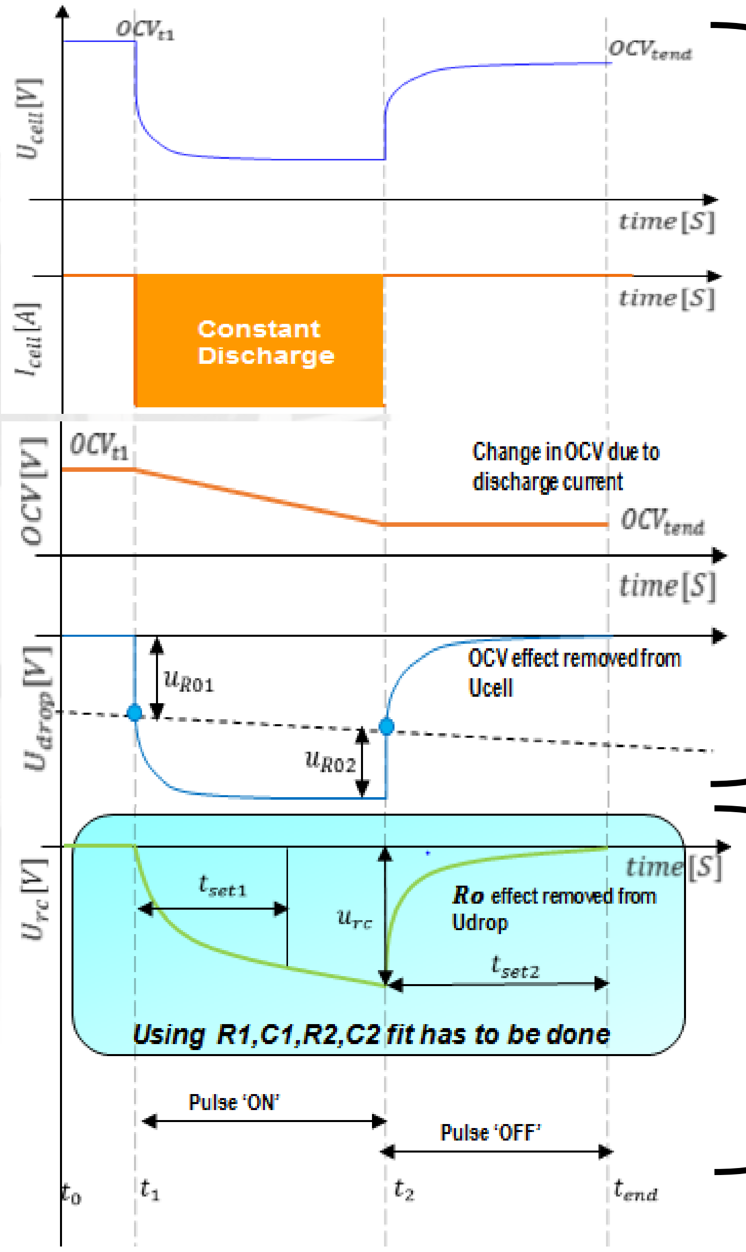
$$t_{set} = 5 * \tau \text{ , where } \tau = RC$$

$$U_{rc} = I_{cell}(R_1 + R_2) \ @\, t = \infty .$$

$$R_{max} = (R_1 + R_2) = {}^{U_{rc}}/_{I_{cell}} \quad @\, t = \infty$$

$$C_{max1} = {}^{t_{set1}}/_{(5 * 0.0001)}$$

$$C_{max2} = {}^{t_{set2}}/_{(5 * 0.0001)}$$

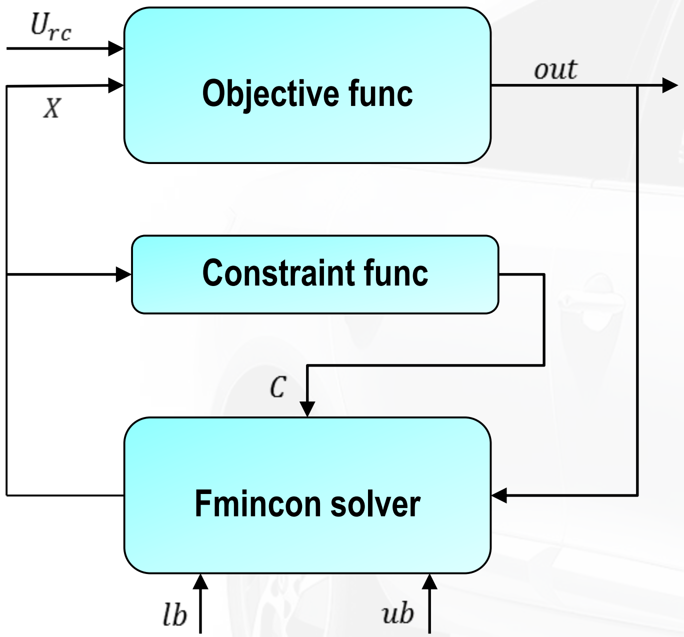



**fmincon**

*Only Urc curve fitted using fmincon function from Matlab*

# OPTIMIZATION

**fmincon(FUN,X,A,B,Aeq,Beq,LB,UB,NONLCON,options,varargin)**




***Nonlinear constraints:***

$C_1 = R_{max} - (X(1) + X(3)).$

$C_2 = t_{set2} - 5 * (X(3) * X(4)).$

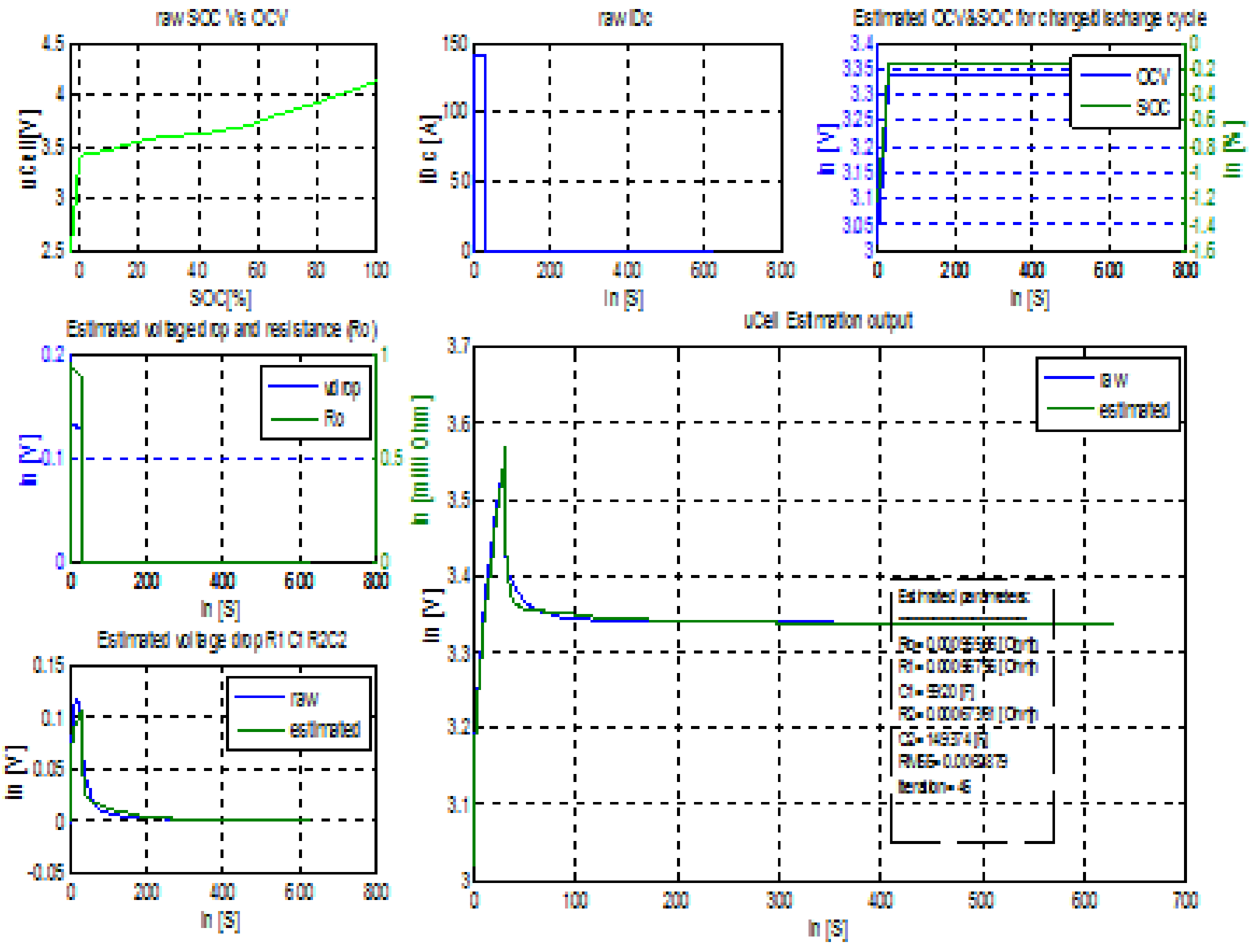
$C_3 = t_{set1} - 5 * (X(1) * X(2)).$

$C_3 = (X(1) * X(2)) - (X(3) * X(4)).$

*C(X) <= 0*

***linear constraints:***

$A = [];\ Aeq = [];\ B = [];\ Beq = [];$

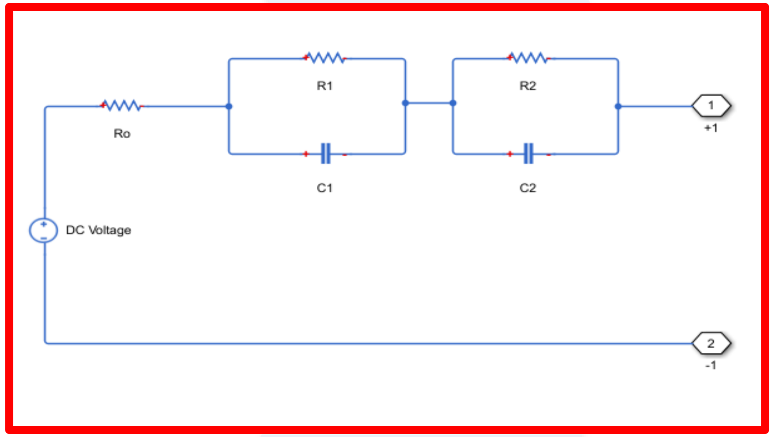


## METHODOLOGY

**Equivalent Circuit Modelling is the most common approach for battery analysis**

**Parameters**

- **Series Resistance *(Ri)***
- **Parallel Resistance *(Rn)***
- **Parallel Capacitance *(Cn)***




**Assumption**

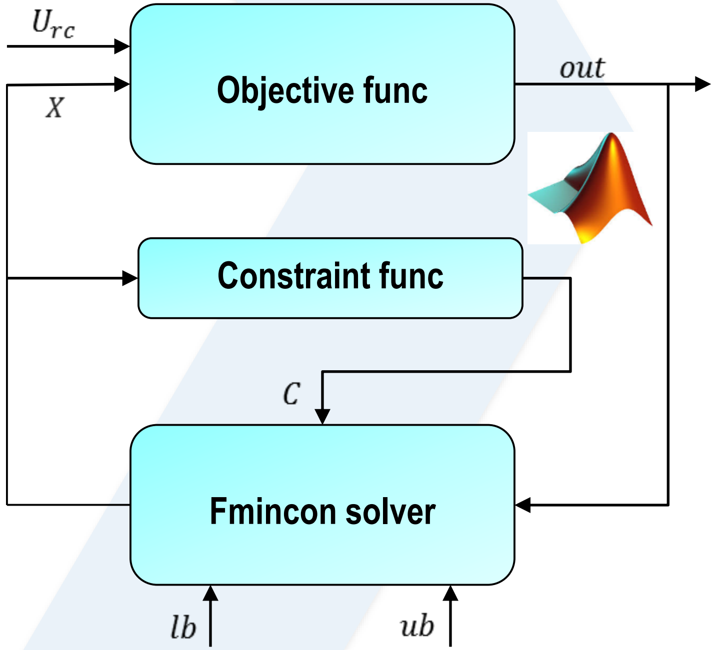
- **No Self discharge**
- **R1,C1 and R2, C2 changes w.r.t SOC in a pulse ON and assumed throughout estimation**
- **1RC parameters derived from 2 RC components.**
- **Over/Under voltage pulses are eliminated.**

## PARAMETER ESTIMATION

**Estimator used here is OPTIMIZATION TOOL**

**Estimation method Fmincon**

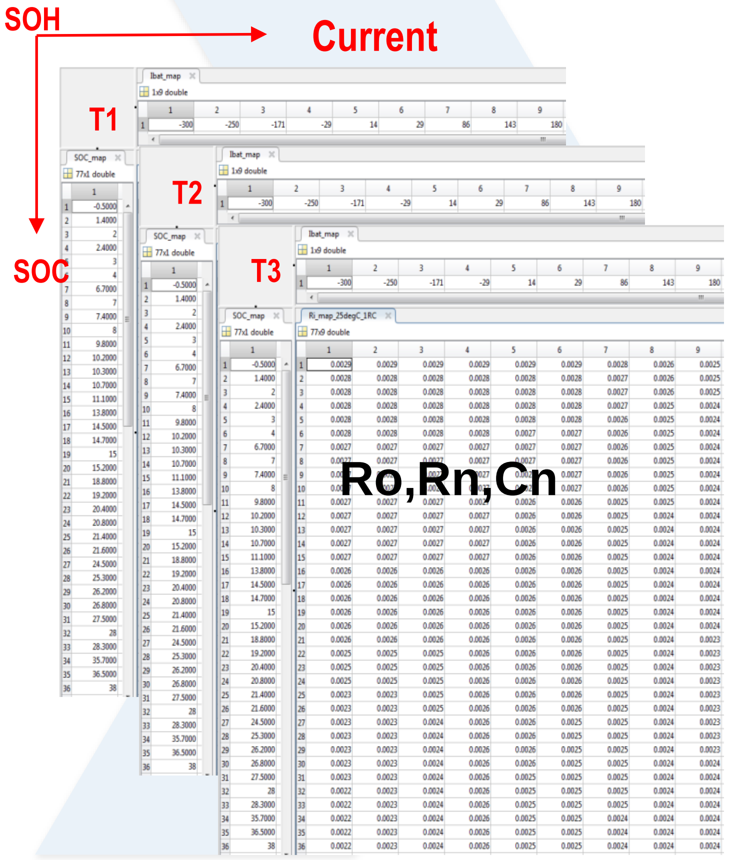
- **Parameters (Ro, Rn, Cn) depends on the Input current, Capacity, SOC and Temperature**



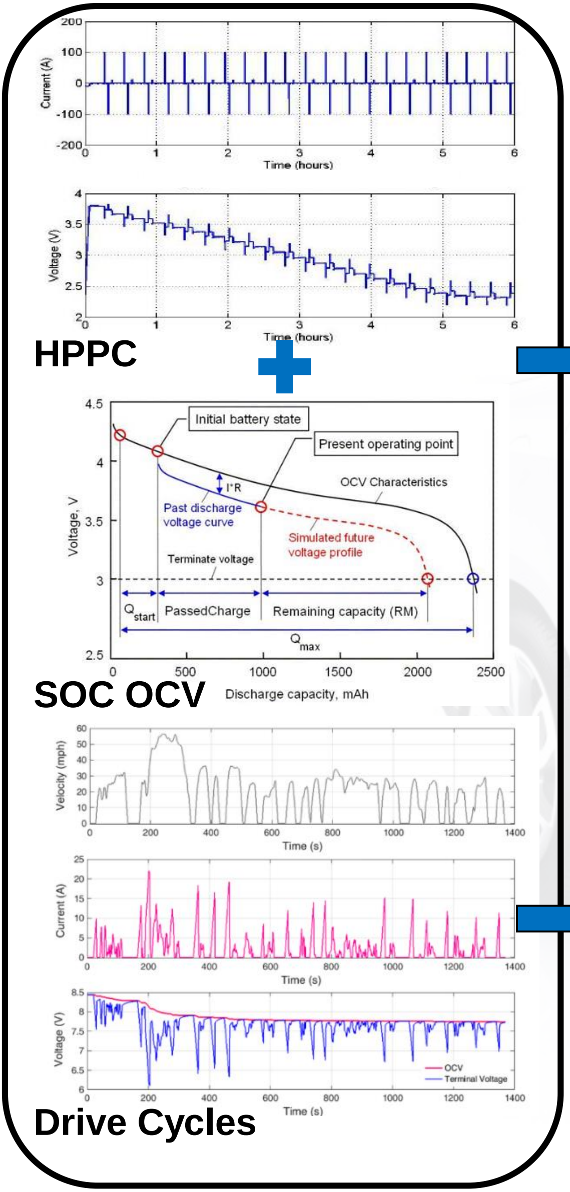

## PARAMETER UPDATION

$$lb = [0.0001, 10, 0.0001, 10]$$

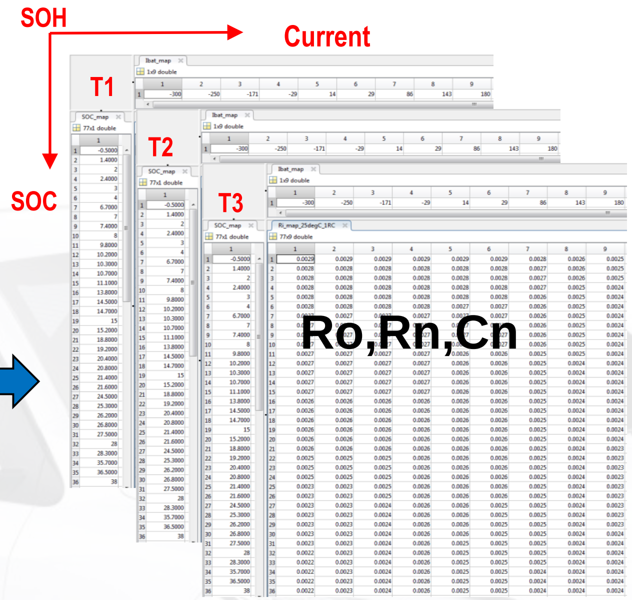
$$ub = [R_{max}, C_{max1}, R_{max}, C_{max2}]$$

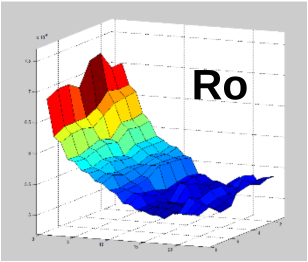


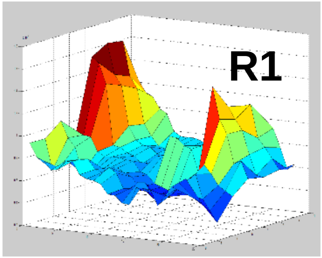
# WORK FLOW

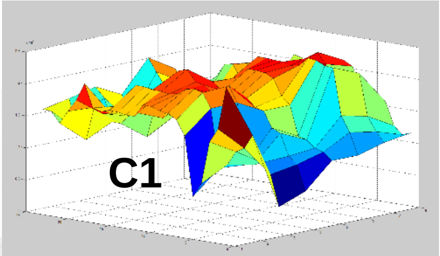


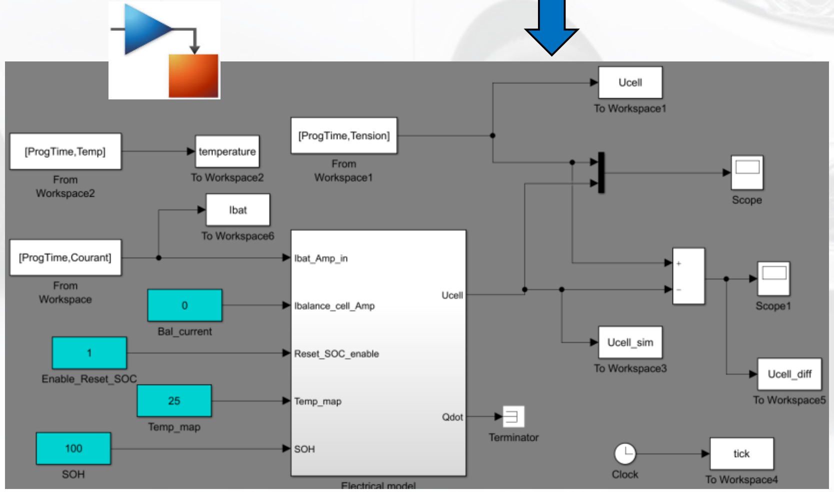

**Parameter Estimation**



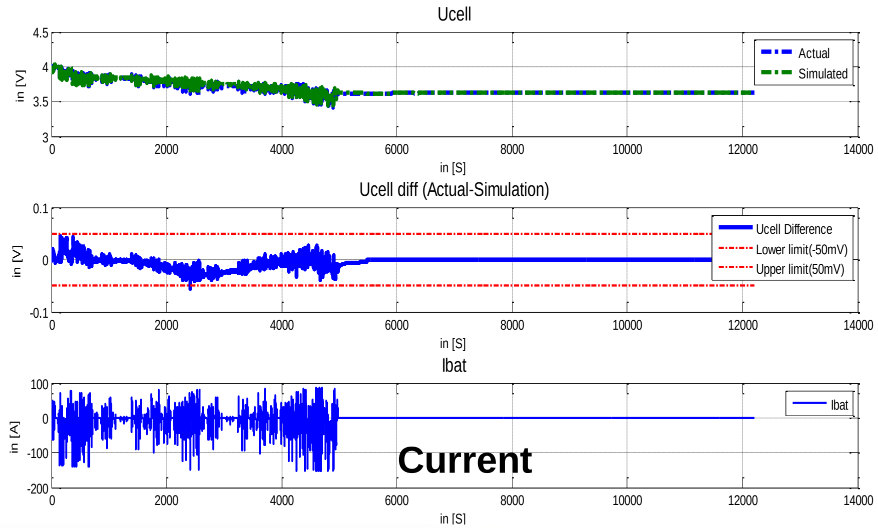



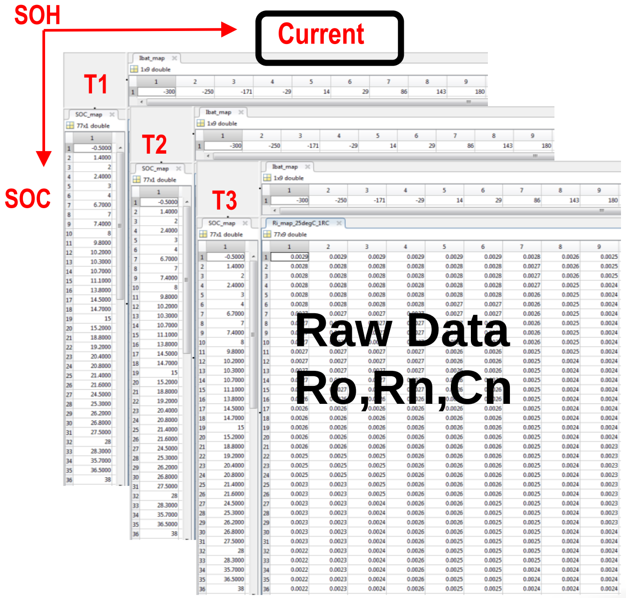



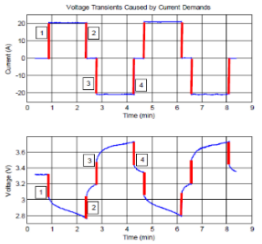

**Battery Plant model**




**Drive Cycle**

# Data reduction

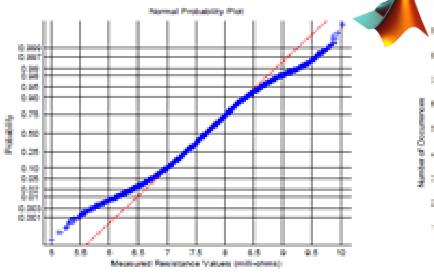


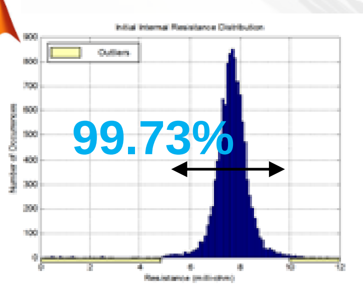

## Out layer rejection

**Normal distribution**

**Remove : > Three standard distribution (99.73%) 3σ**




Comparison of Normal Distribution to Observed Resistance Value




Sample Distribution of Resistance Values

## Centered Moving Avg filtering

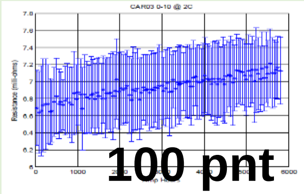
$$R_{avg}(k) = \frac{R\left(k - \frac{group}{2}\right) + \cdots + R(k) + R\left(k + \frac{group}{2}\right)}{group}$$

$$k = n * group$$

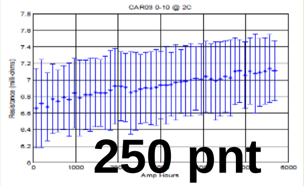
$$n = 1, 2, 3, 4, \ldots$$

$$k = group + n * slide$$

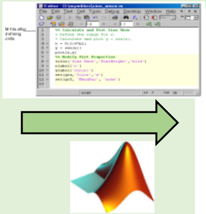
$$n = 0, 1, 2, 3, 4, \ldots$$

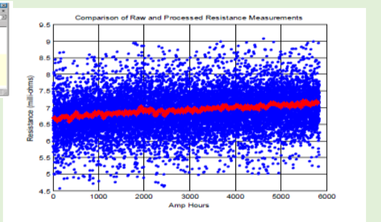



CAR 03 Sliding Average – 100 Points




CAR 03 Sliding Average – 250 Points






Raw Resistance Values and Averaged Resistance Values

**Raw data**

↓

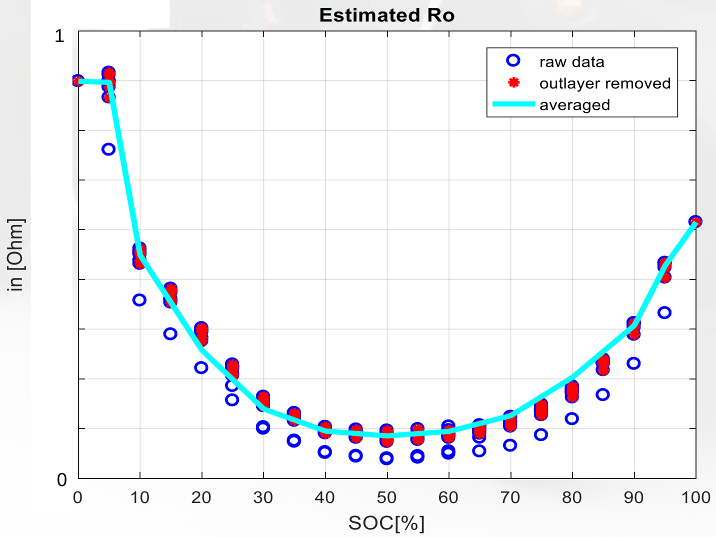
**Remove non boundary values**

↓

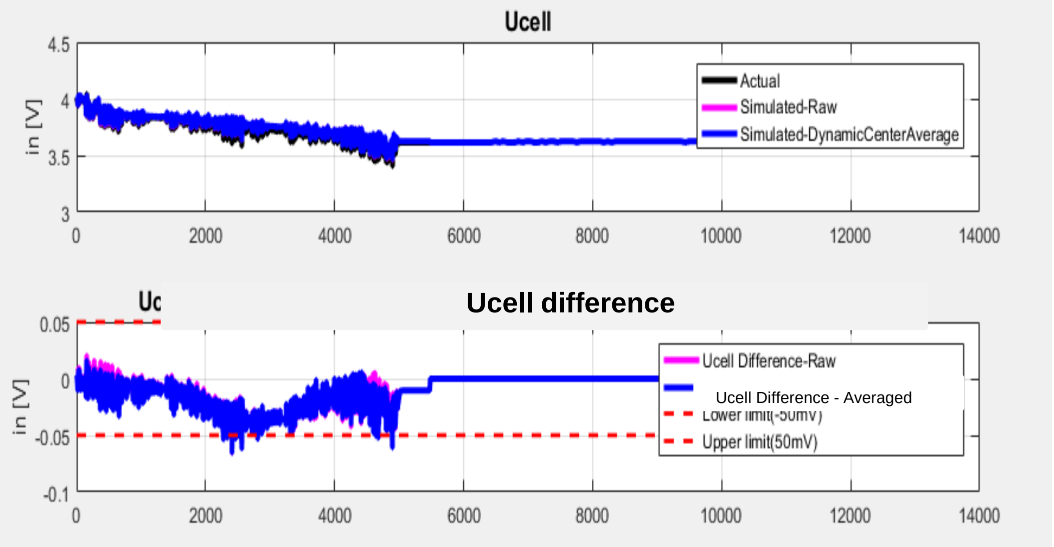
**Out layer rejection**

↓

**Averaging filter**

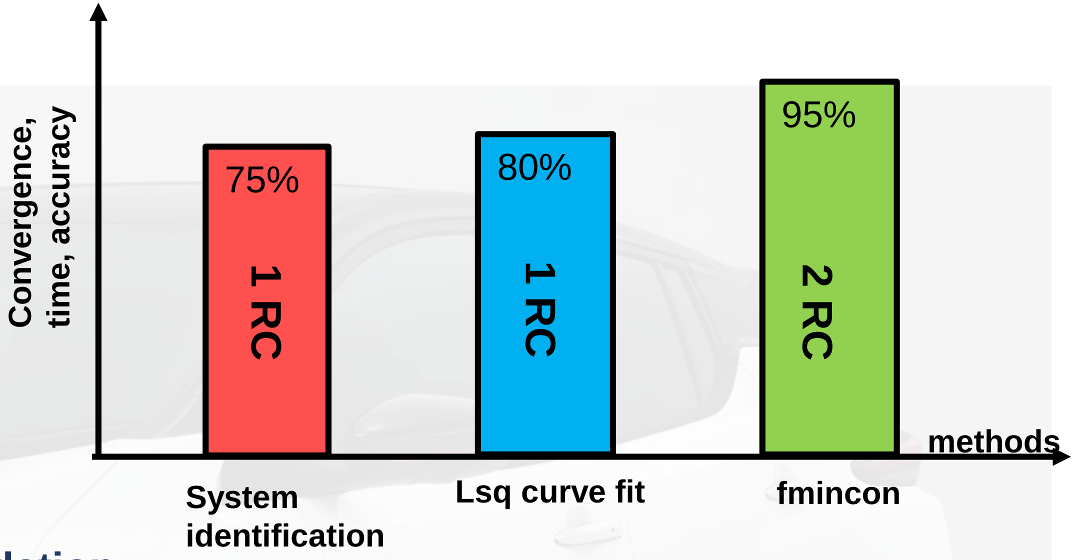



## Raw Data vs Reduced Data

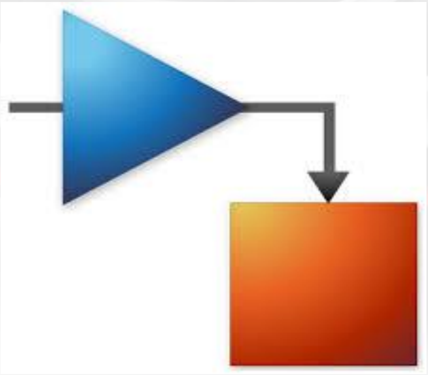


# BENEFITS

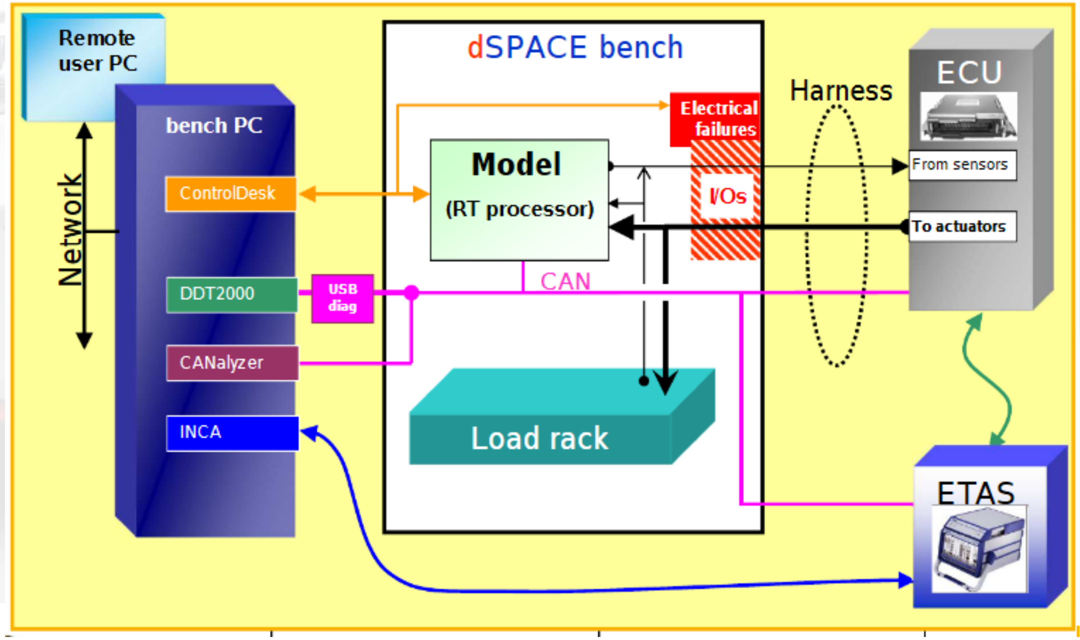
- Less Complex Model
- Faster Parameter Estimation
- 95% of accuracy in tuning parameters
- Effective capturing of nonlinear effects
- No manual tuning of parameters required for validation




*Plant model with the estimated parameters are used in the HIL test bench*



Battery Plant model



# MATLAB ASSISTANCE

- Battery Test Bench
- Excel : Data Collecting
- Data Extraction : Pulses & Validation Data *(m-script)*
- Valid Pulse Check (data validity) *(m-script)*
- Estimation of Parameters *(Optimization toolbox)*
- Data Reduction *(statistics toolbox )*
- Validation with Plant Model *(Simulink:-Simscape)*
- Battery Pack Generation *(Simulink & m-script)*
- Battery Pack Comparison with HV Test Bench *(m-script)*

Automated

- **Helped in handling a huge data (>10GB)**
- **Easy to analyze data**
- **Make robust automation**
- **Estimated results used in HIL/MIL**
- **Reduced data are used ASW calibration**

# REFERENCES


- *“Battery testing procedures” - Maciej Swierczynski*
- *“How to model a battery, is a source and a resistor enough?” - J.M. Timmermans*
- *https://www.google.fr/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjGpamq2t7YAhUGYlAKHYw8BtEQFggnMAA&url=https%3A%2F%2Fetd.ohiolink.edu%2F!etd.send_file%3Faccession%3Dosu1306937891%26disposition%3Dinline&usg=AOvVaw3o10OzmcBNe7YSk33hHkF_*


Q&A

# THANK YOU

GO GREEN

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