

14 juni 2018  
1931 Congrescentrum Den Bosch

**POWER**  
**ELECTRONICS**

2018

**TT&MS**

*total test and measurement support*

*René Bos, **T&M** Consultant*

Den Bosch

14 juni 2018

# Batterij Emulatie

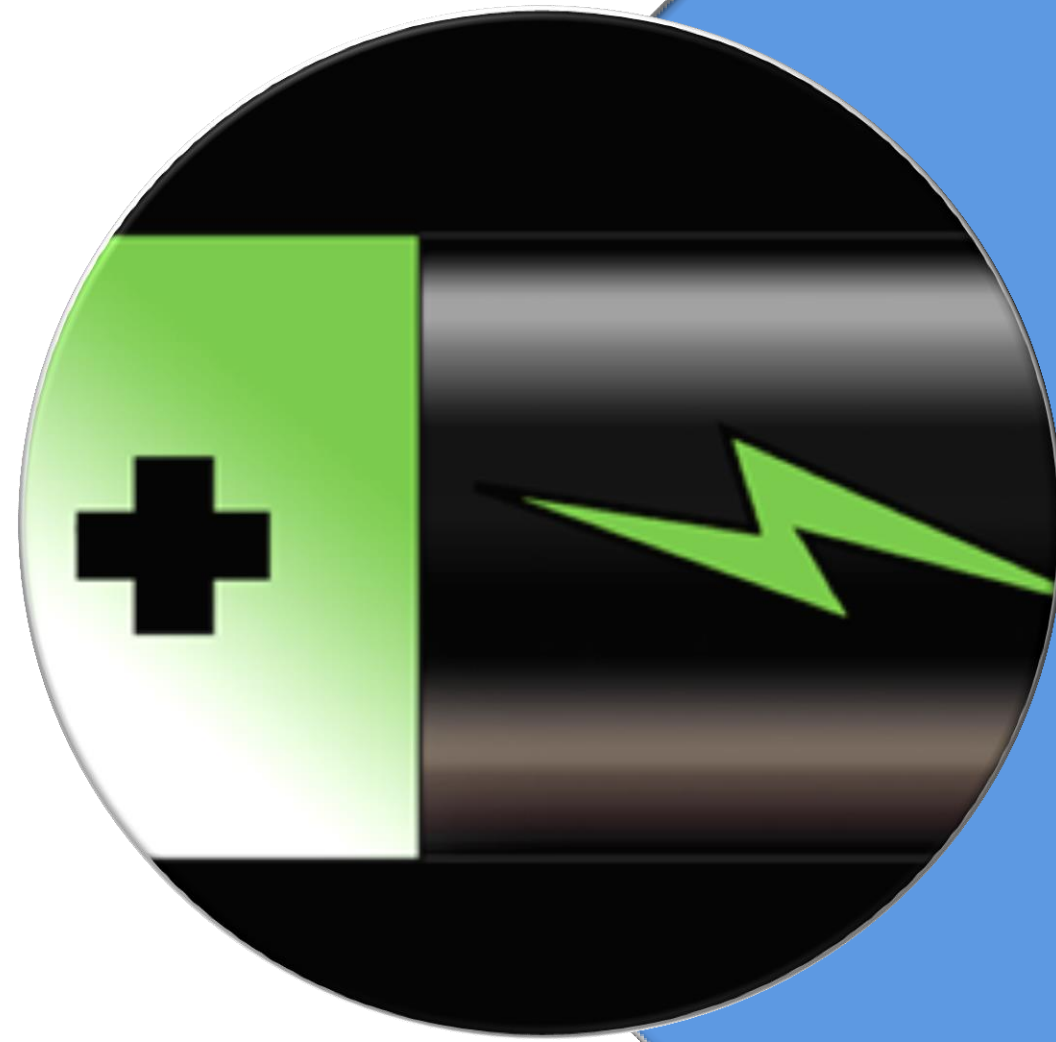
## **TT&MS** Area of Expertise





***TEST & MEASUREMENT IS  
OUR KNOWLEDGE,***

***SUPPORTING CUSTOMERS  
OUR BUSINESS.***



## Batterij Emulatie

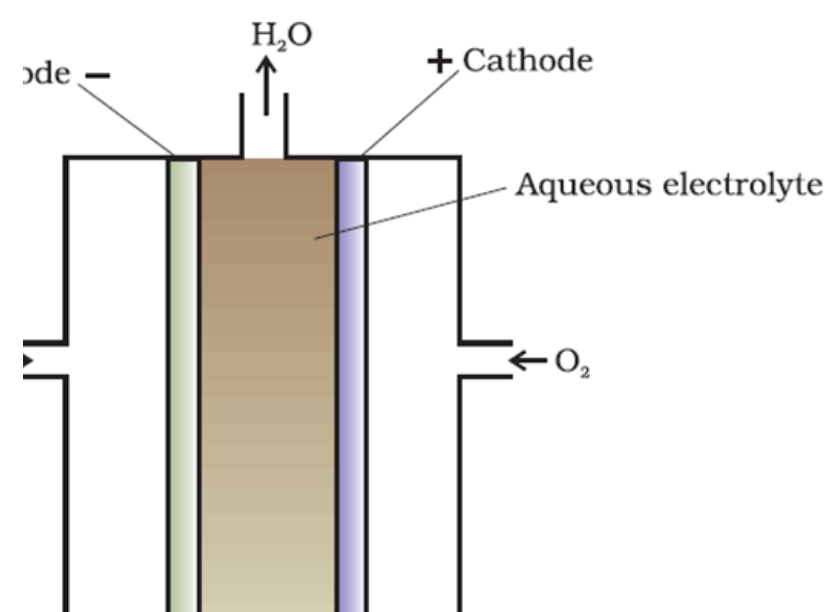
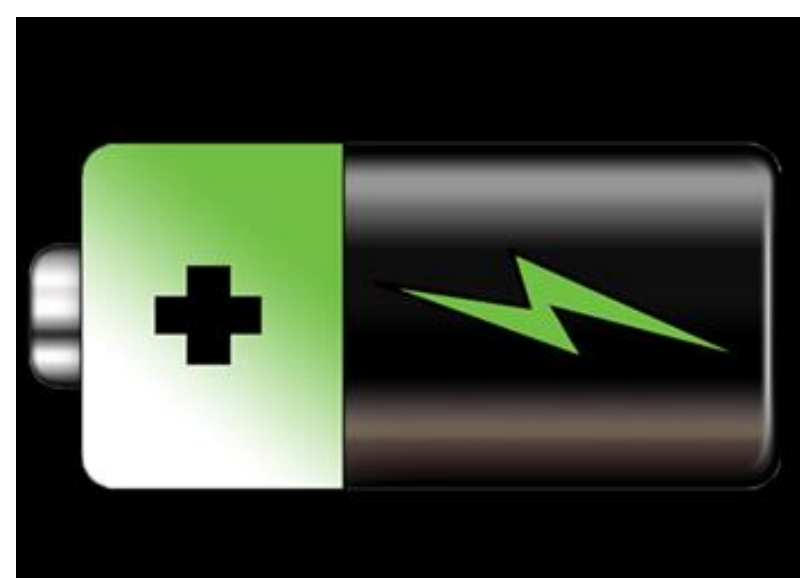
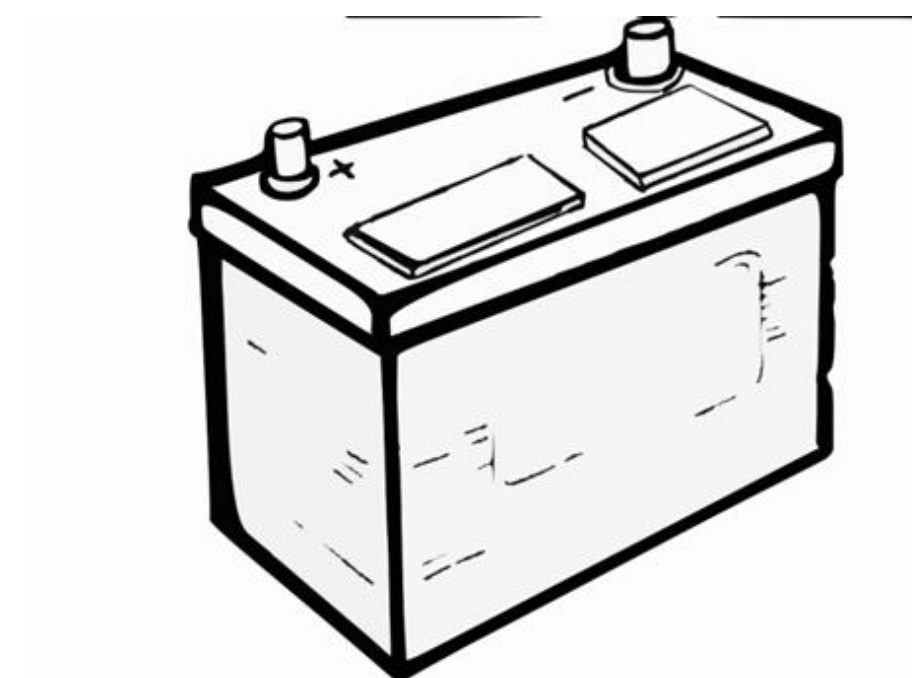
- De elektrochemische cel
- Opbouw cel
- Waarom batterij emulatie
- Praktische oplossingen
- Conclusie

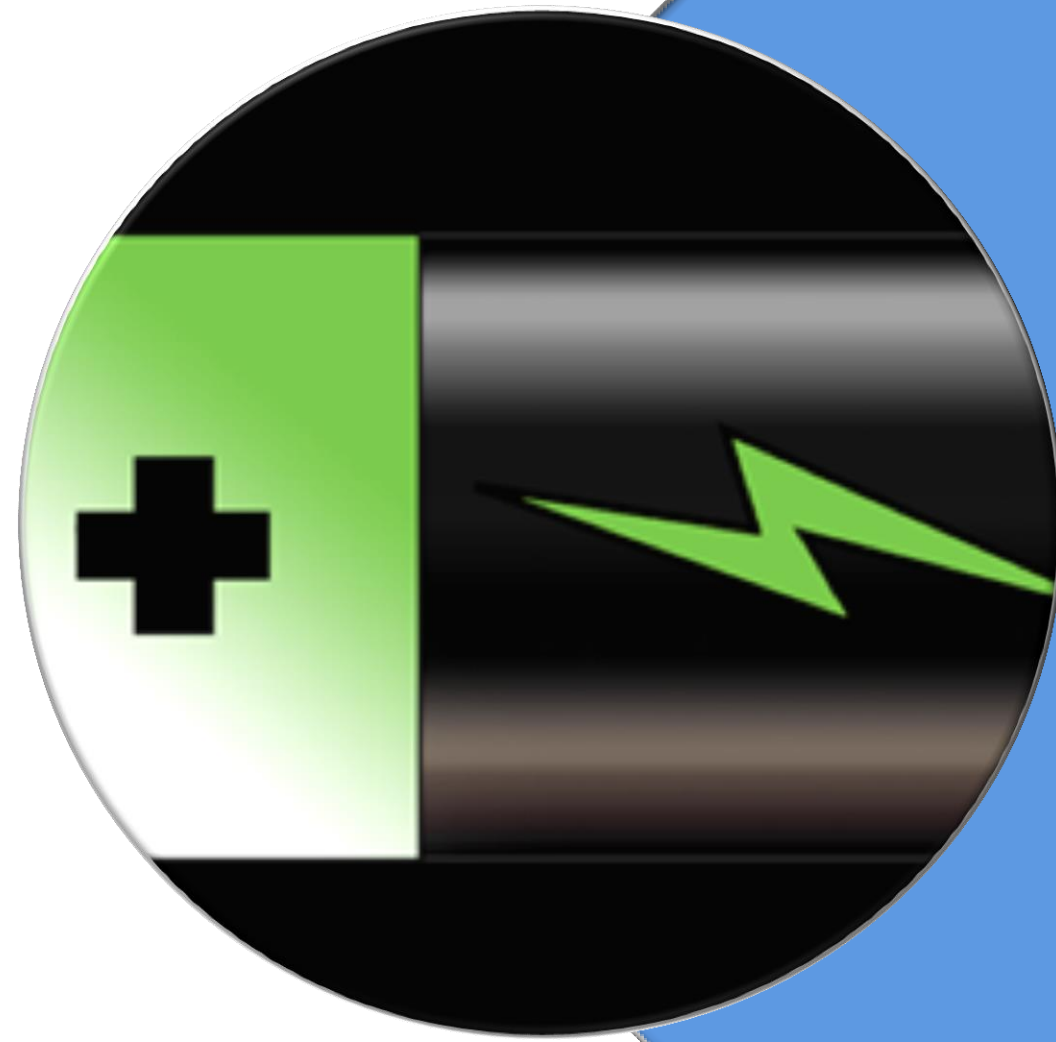
# Batterij Emulatie: De elektrochemische cel

- Energieopslag, in de vorm van batterijen, accu's, fuel cellen, is actueel.
- Uitdaging als het gaat om het testen van de benodigde vermogenselektronica.
- Toepassing van een flexibel inzetbare batterij emulator.
- De interne weerstand, dynamic charging / discharging, bipolaire en regeneratieve concepten.



# Batterij Emulatie: De elektrochemische cel



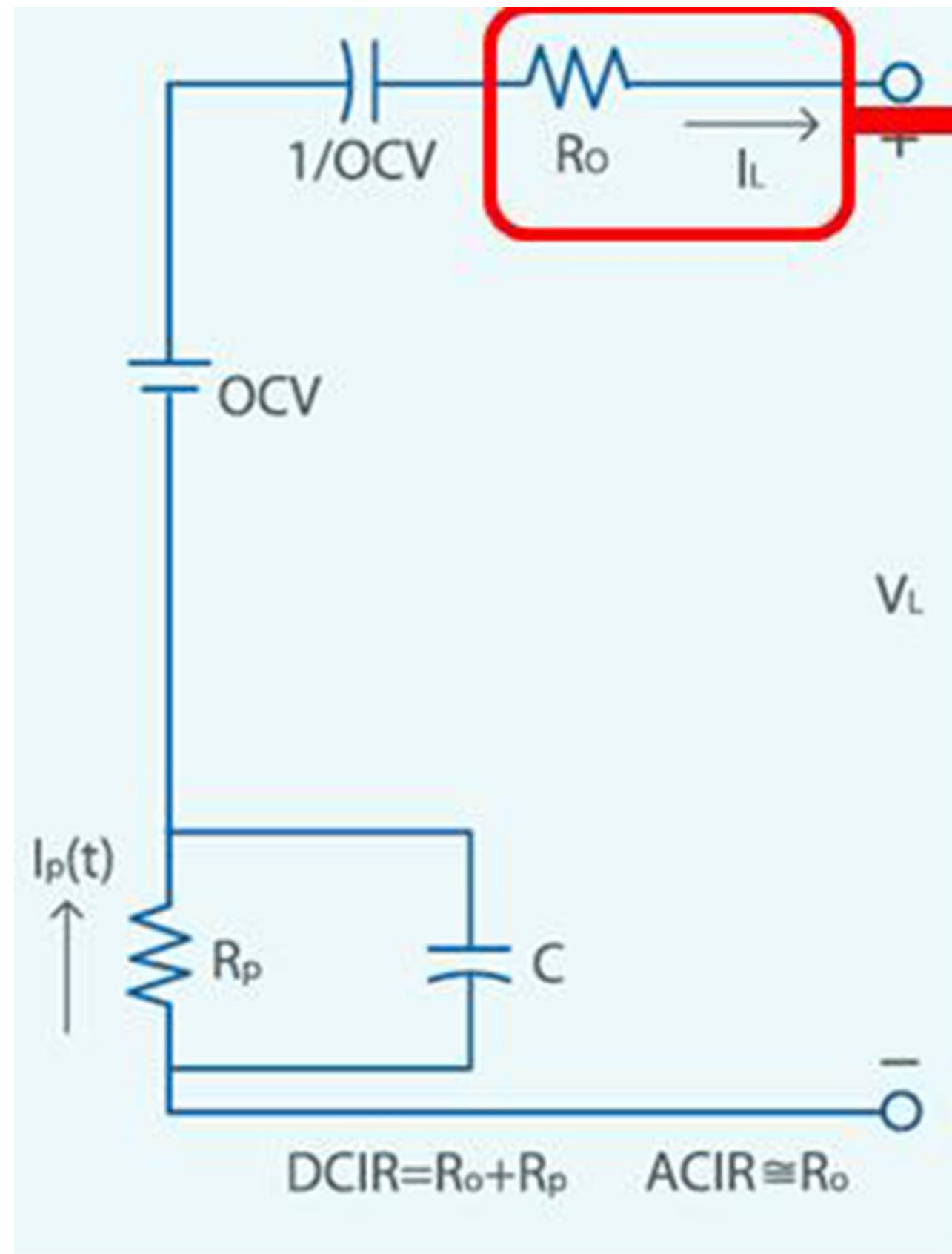


## Batterij Emulatie

- De elektrochemische cel
- Opbouw cel
- Waarom batterij emulatie
- Praktische oplossingen
- Conclusie

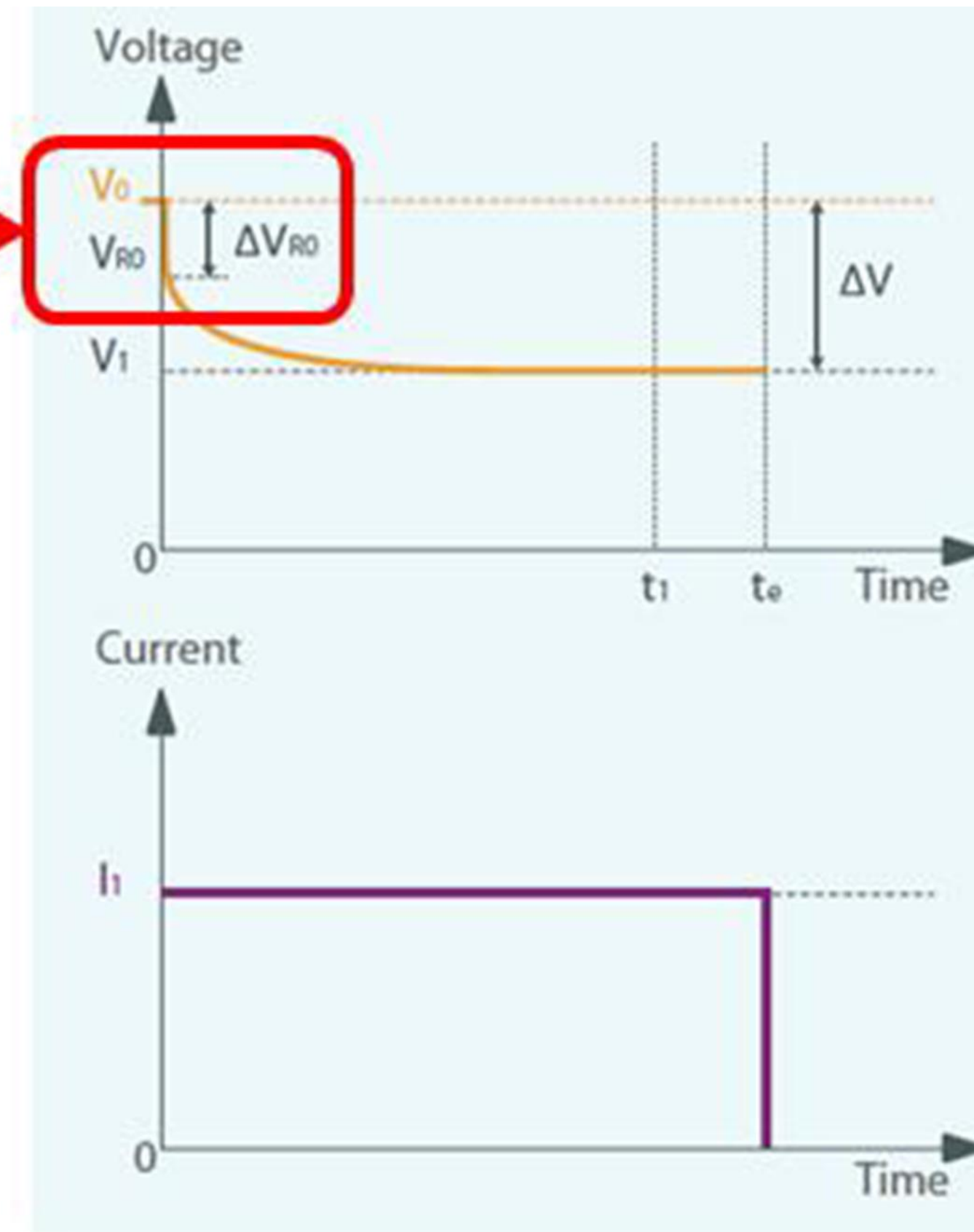
# Batterij Emulatie: Opbouw cel

Battery voltage is impacted by impedance of battery cell



Battery Cell

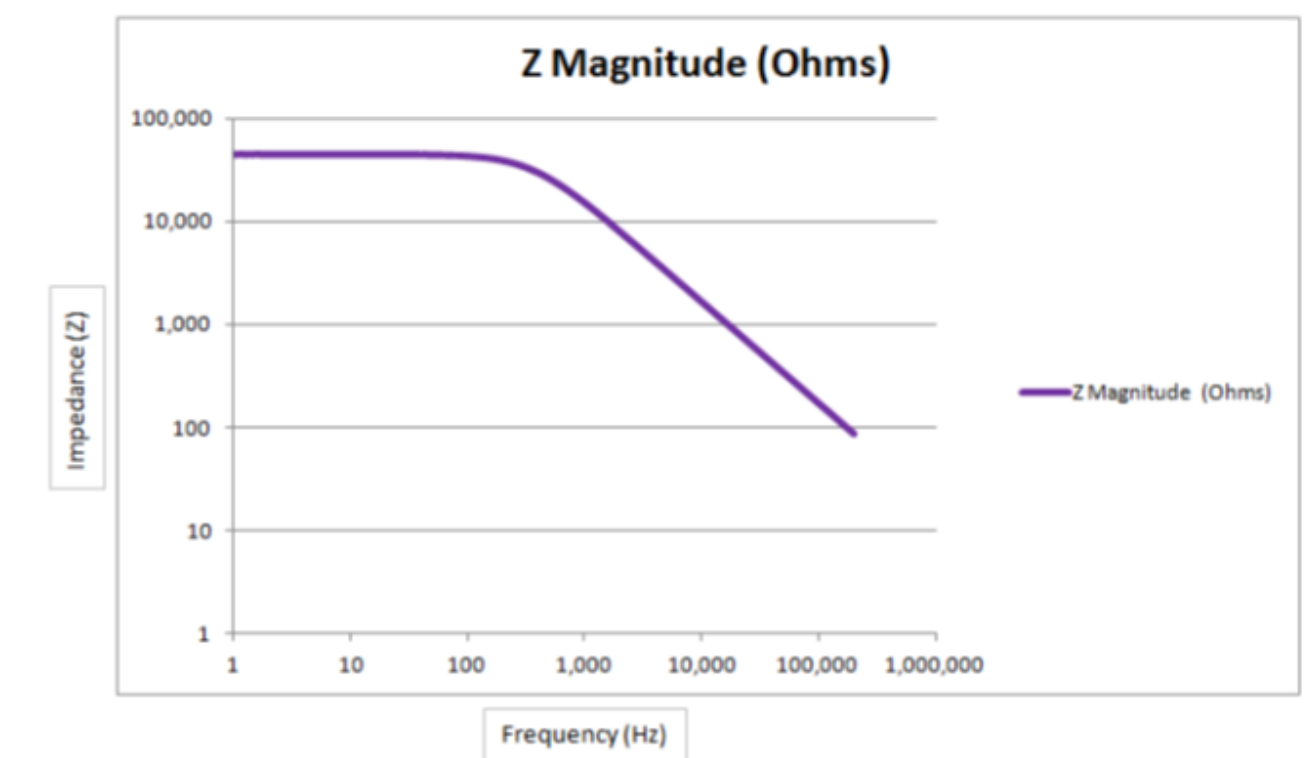
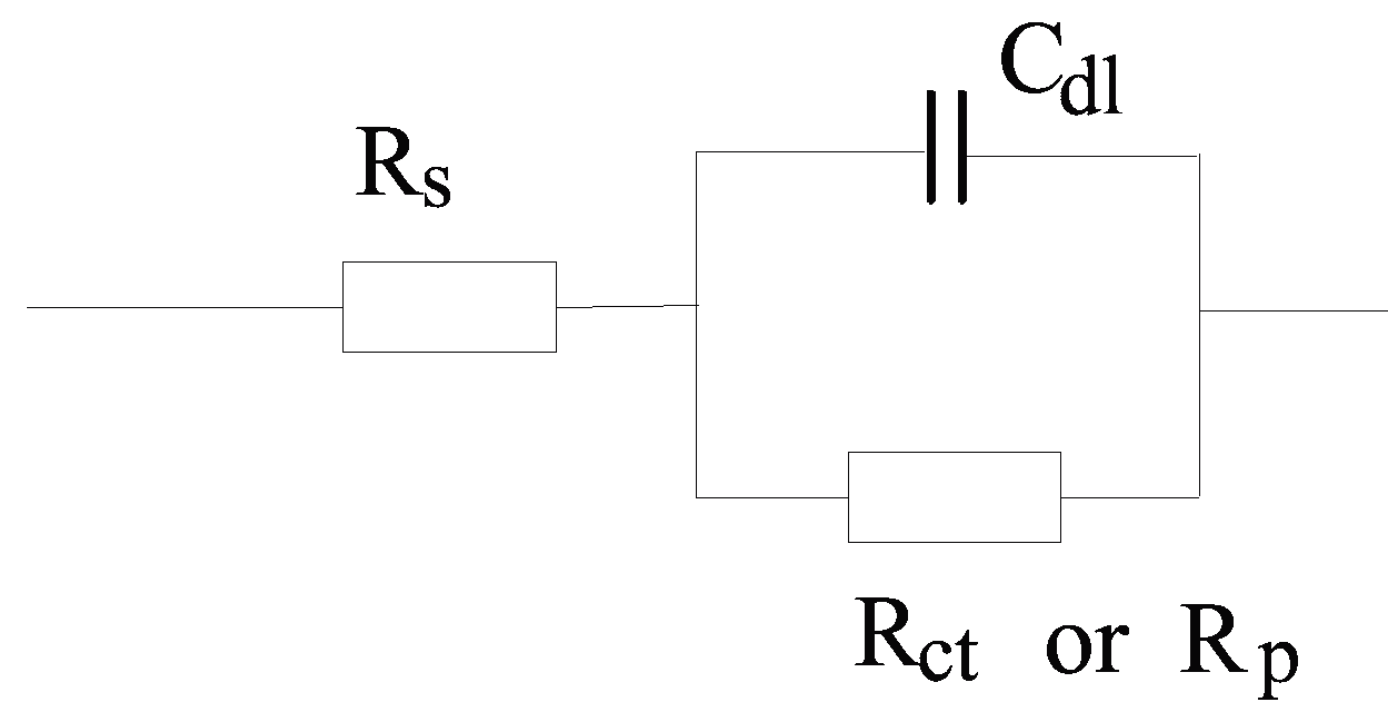
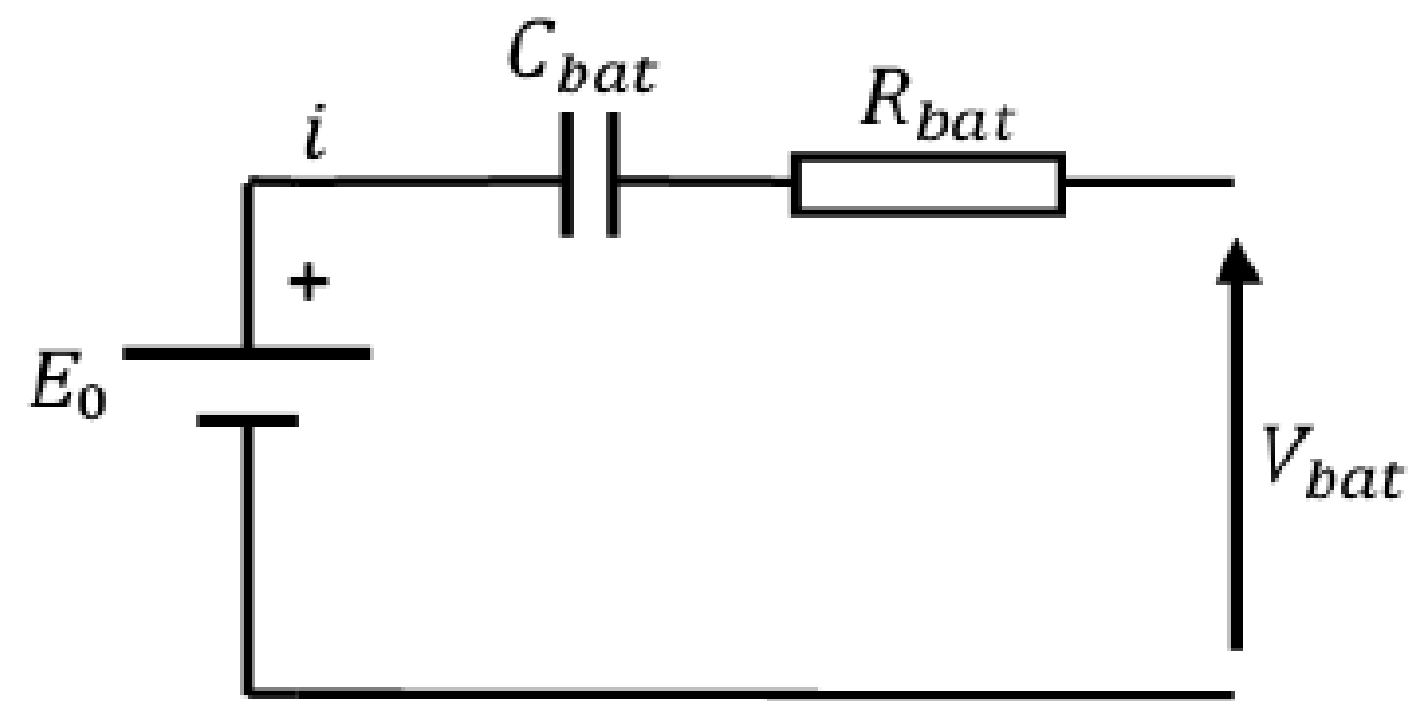
Discharge



Discharge



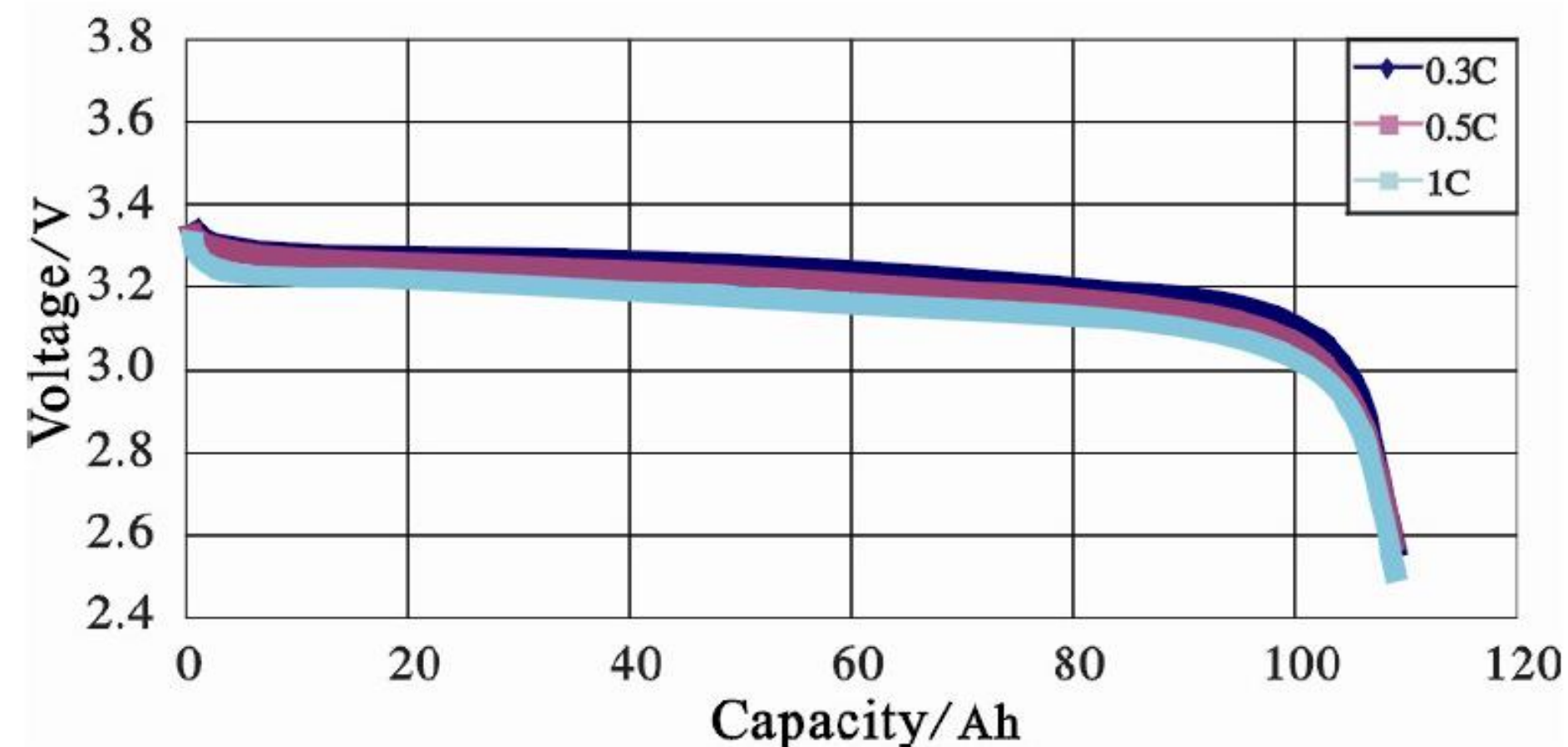
# Batterij Emulatie: Opbouw cel



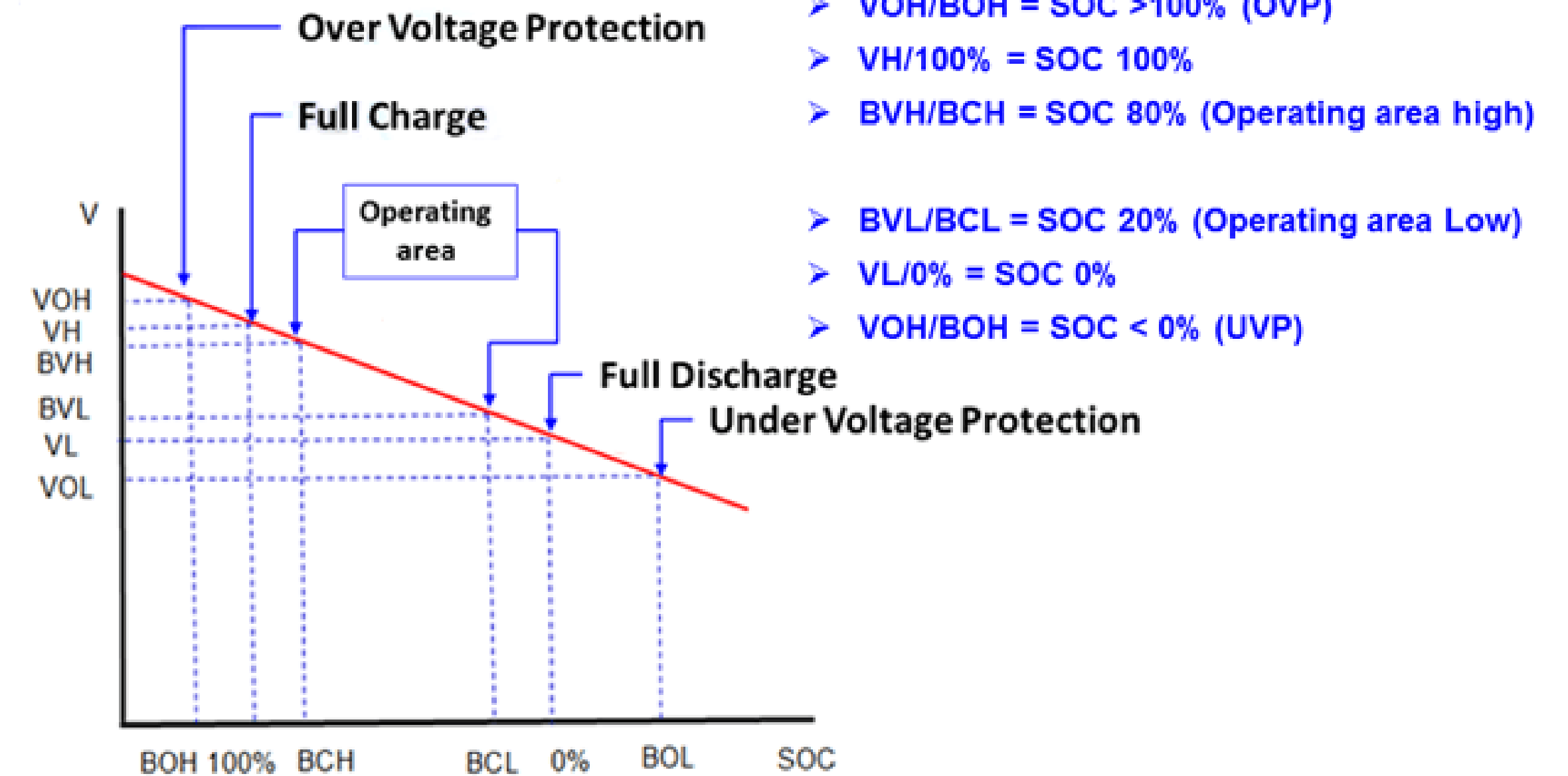
## State of Charge ! (SOC)

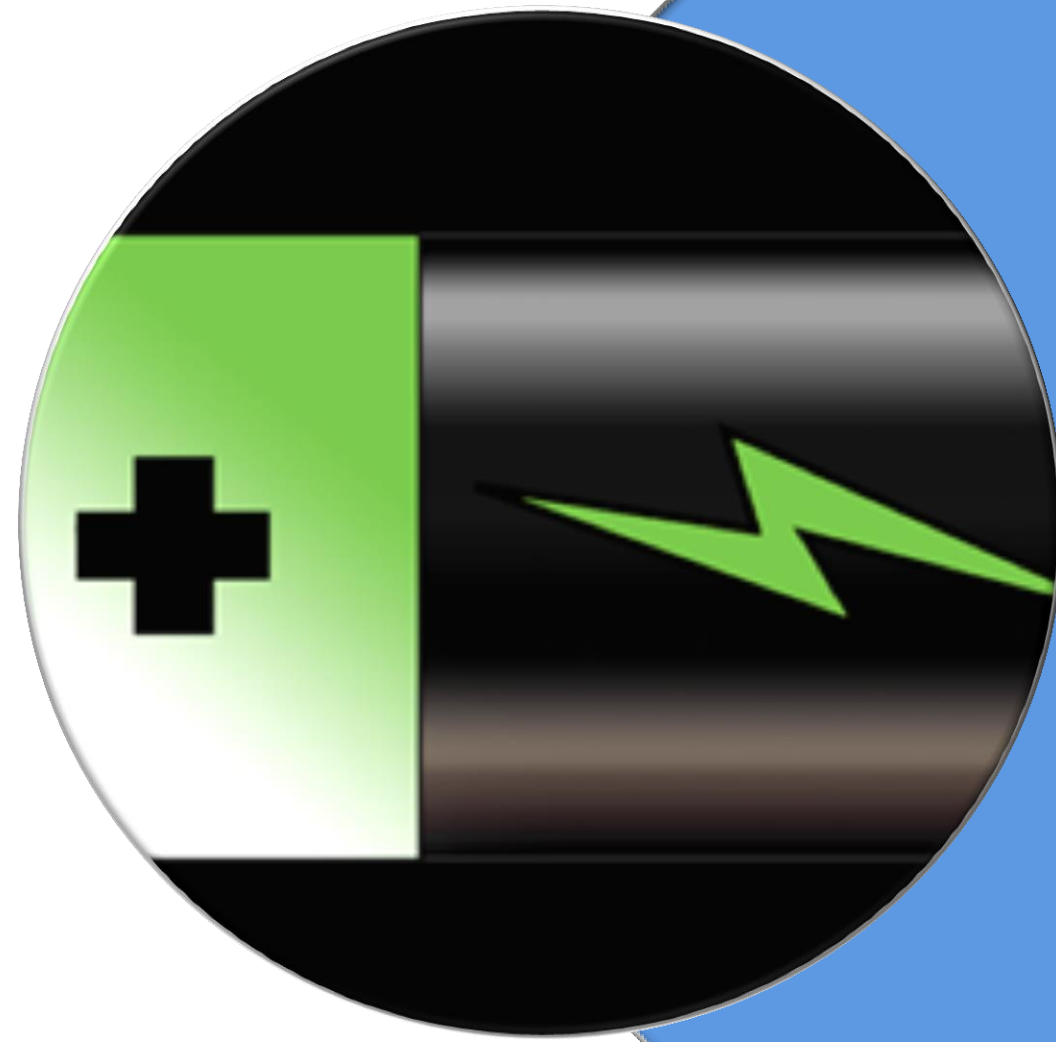
Defines the Operating voltage  
Full charge / full discharge,  
Protection condition of battery pack

discharging curve :



Voltage v.s. SOC(Capacity)





## Batterij Emulatie

- De Elektrochemische cel
- Opbouw cel
- Waarom batterij emulatie
- Praktische oplossingen
- Conclusie

## Waarom batterij emulatie?

- Een (geschikte) batterij is niet altijd voorhanden.
- Is niet altijd eenvoudig samen te stellen.
- Beperkte flexibiliteit.
- Handteerbaarheid.
- Veiligheid.

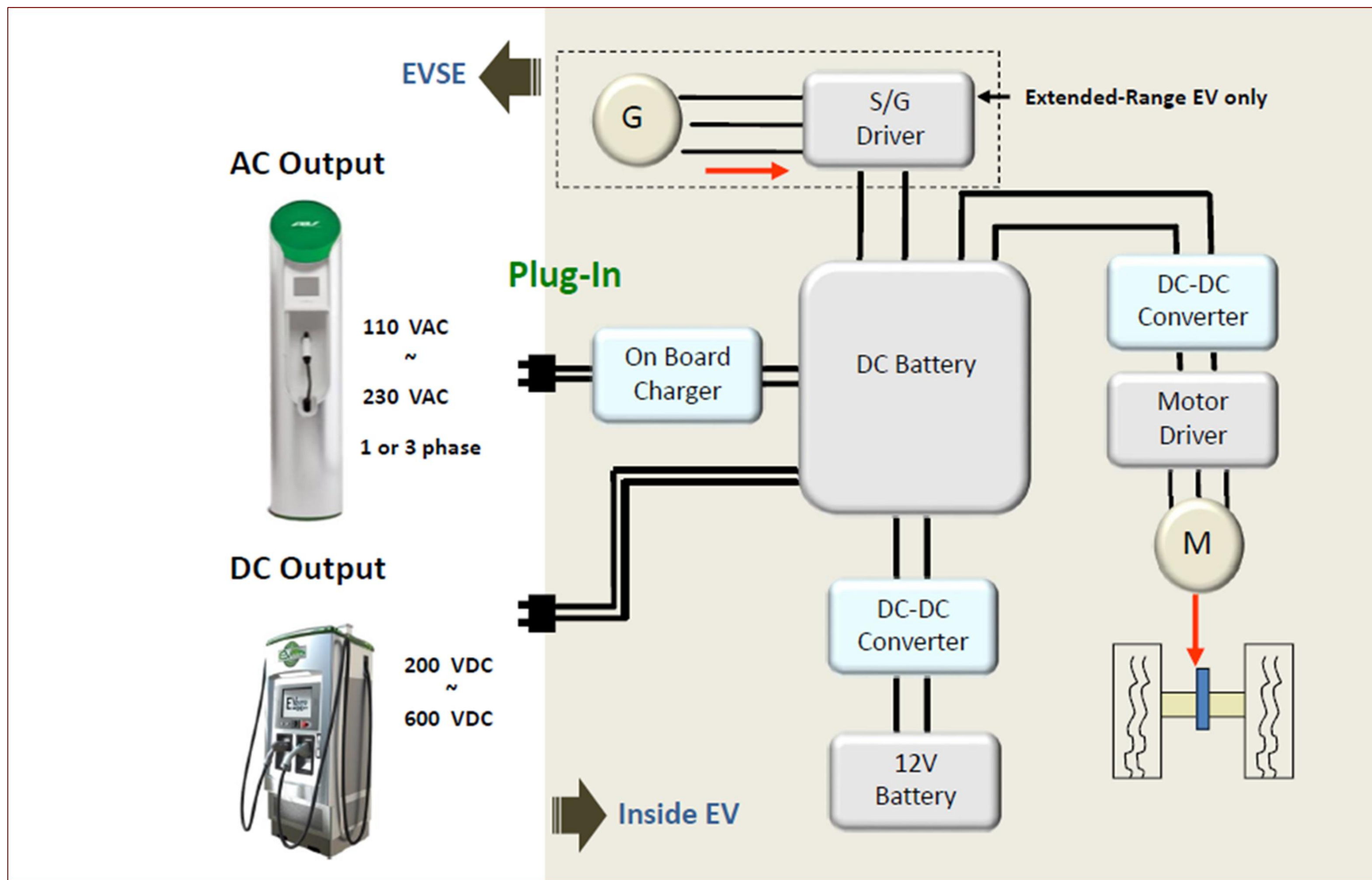


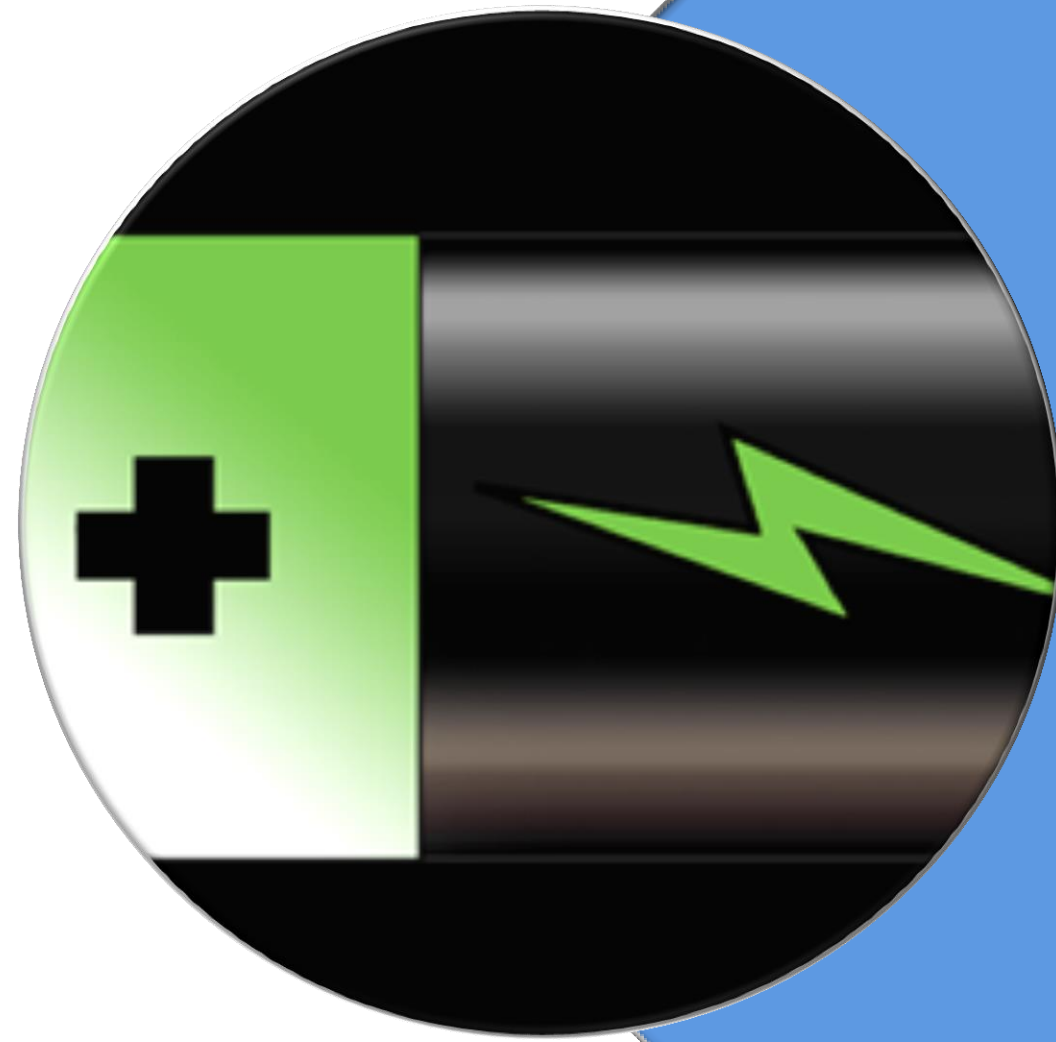
## Waarom batterij emulatie?

- Is letterlijk een gewichtige zaak.
- Kosten.
- Reproduceerbaarheid.
- Reductie in test- / evaluatietijd.
- Snelle aanpassing gewenste parameters.



## Inzetbaarheid van een batterij simulator?





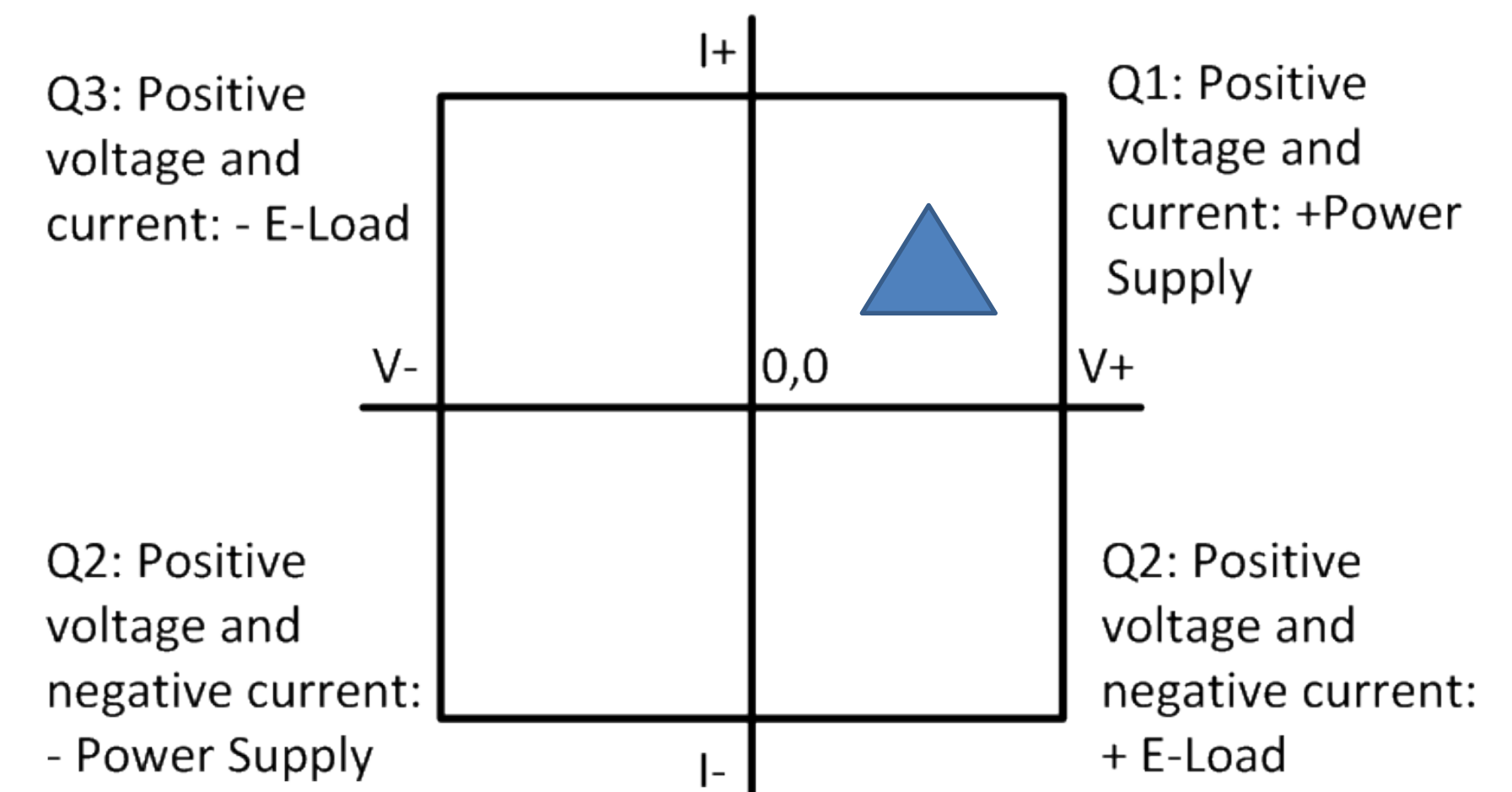
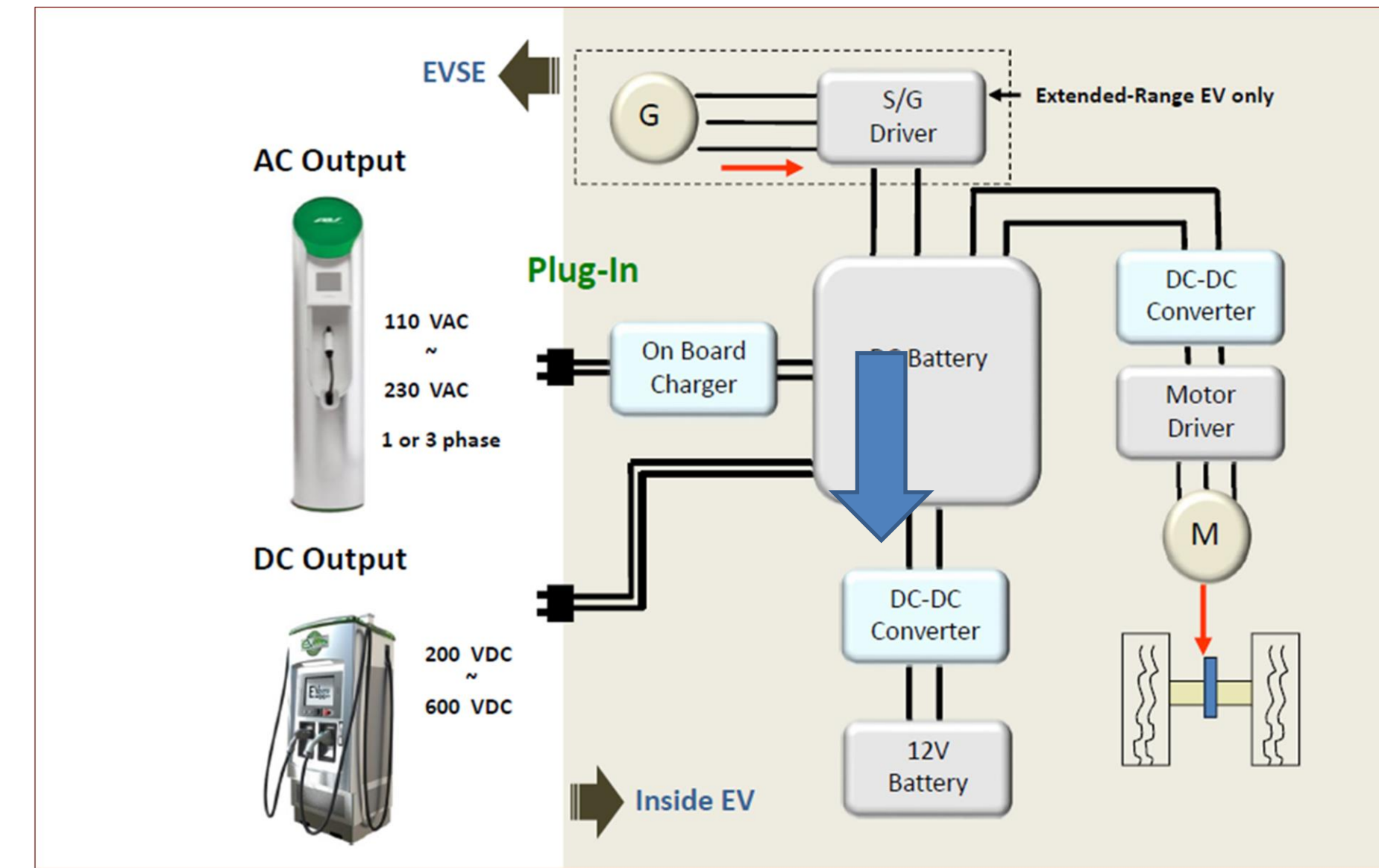
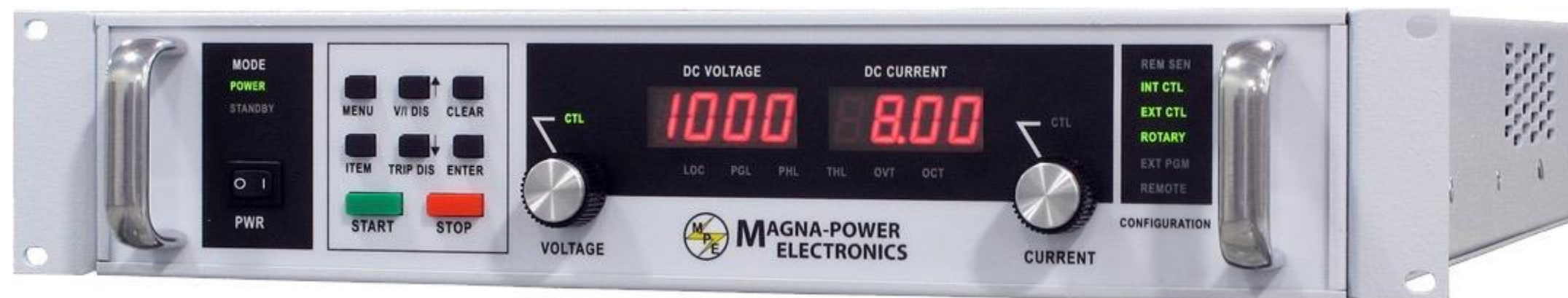
## Batterij Emulatie

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# Batterij Emulatie: Praktische oplossingen

## Programmeerbare DC Power Supply

- DC power supplies worden gebruikt in een ongekend aantal toepassingen.
- Enorme variatie in spanning- / stroombereiken.
- Leverbaar vanaf enkele (m)watts tot vele Mwatts.
- Veelal 1 kwadrant.

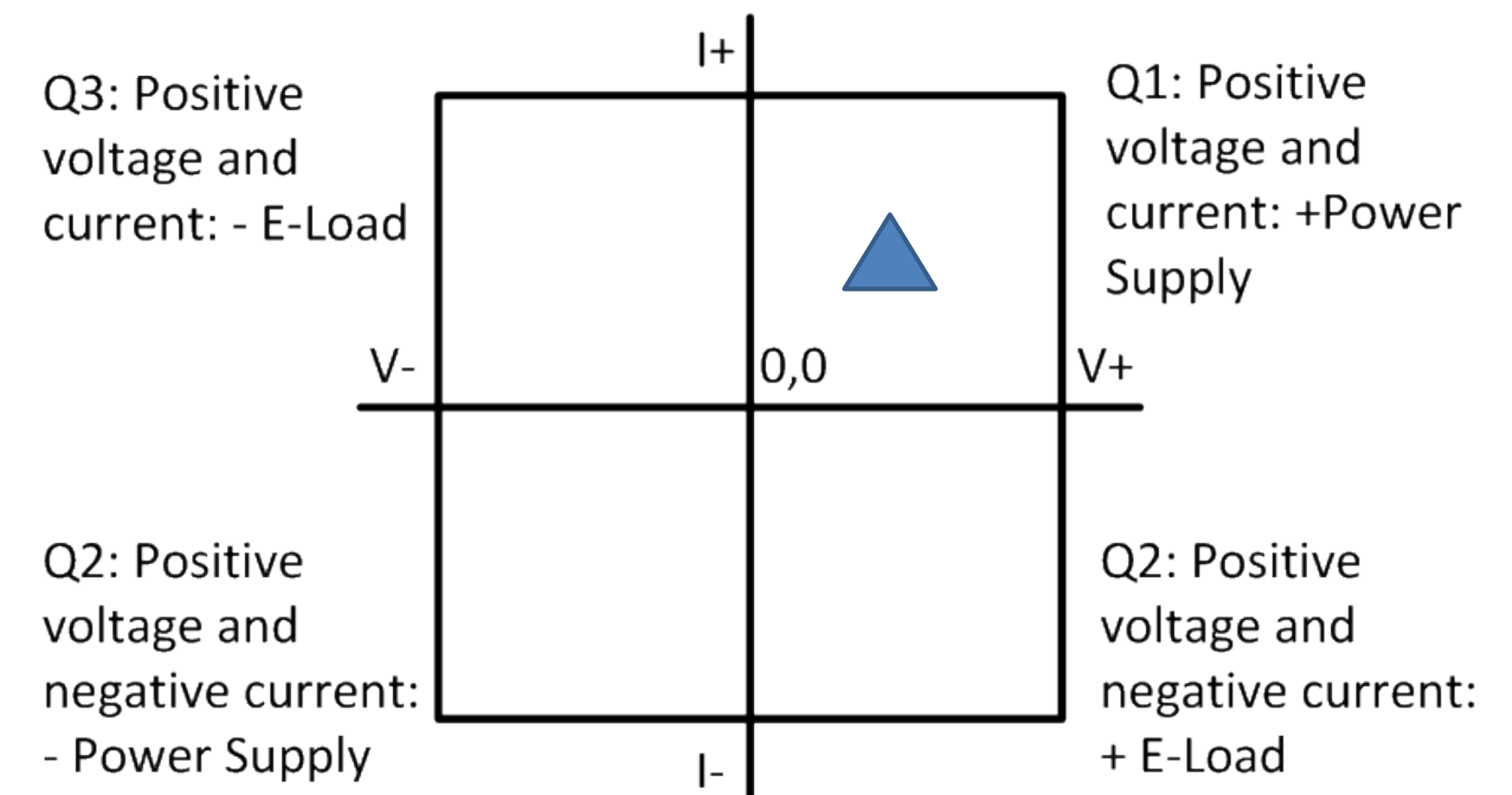
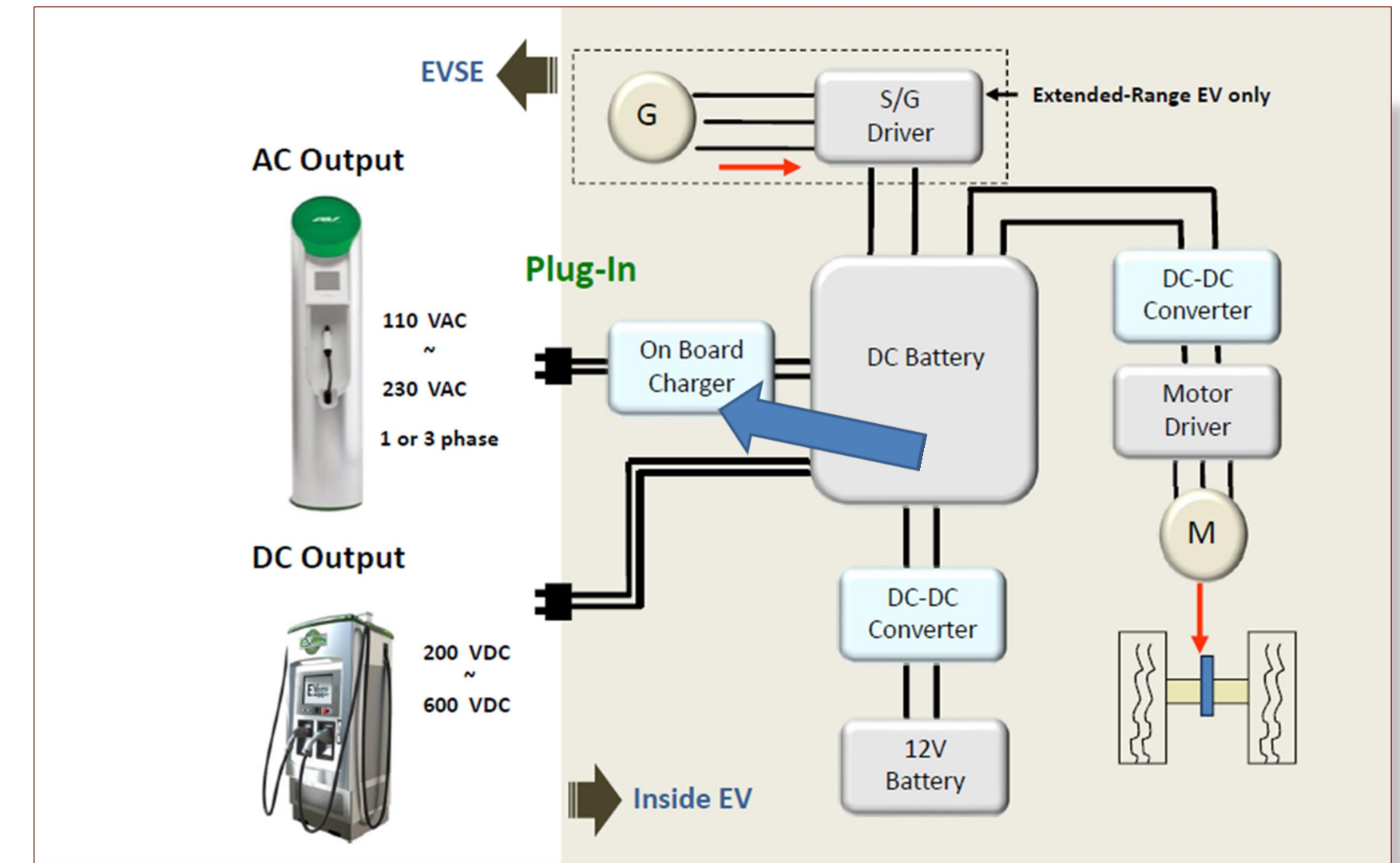




# Batterij Emulatie: Praktische oplossingen

## DC power supply Ri instelbaar

- Programmeerbare output impedantie.
- Ingebouwde functie voor instellen Ri.
- Battery laad- / ontlaadtesten (in combinatie met DC load).
- Simulatie van batterij wordt benaderd.

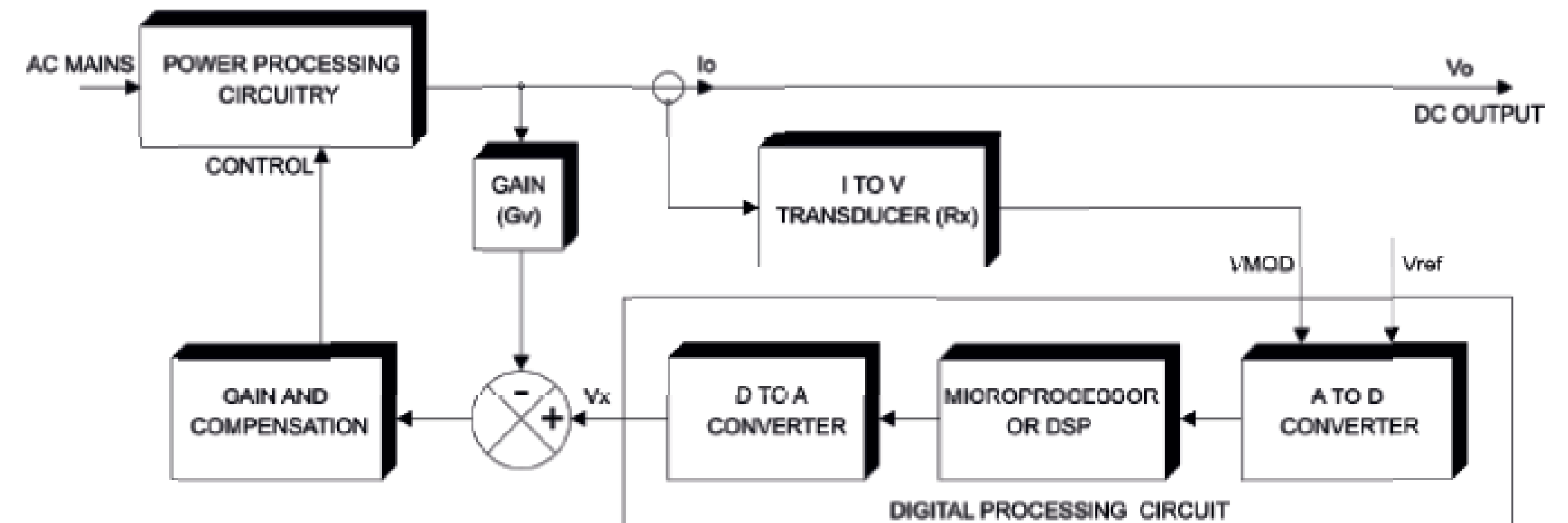


# Batterij Emulatie: Praktische oplossingen

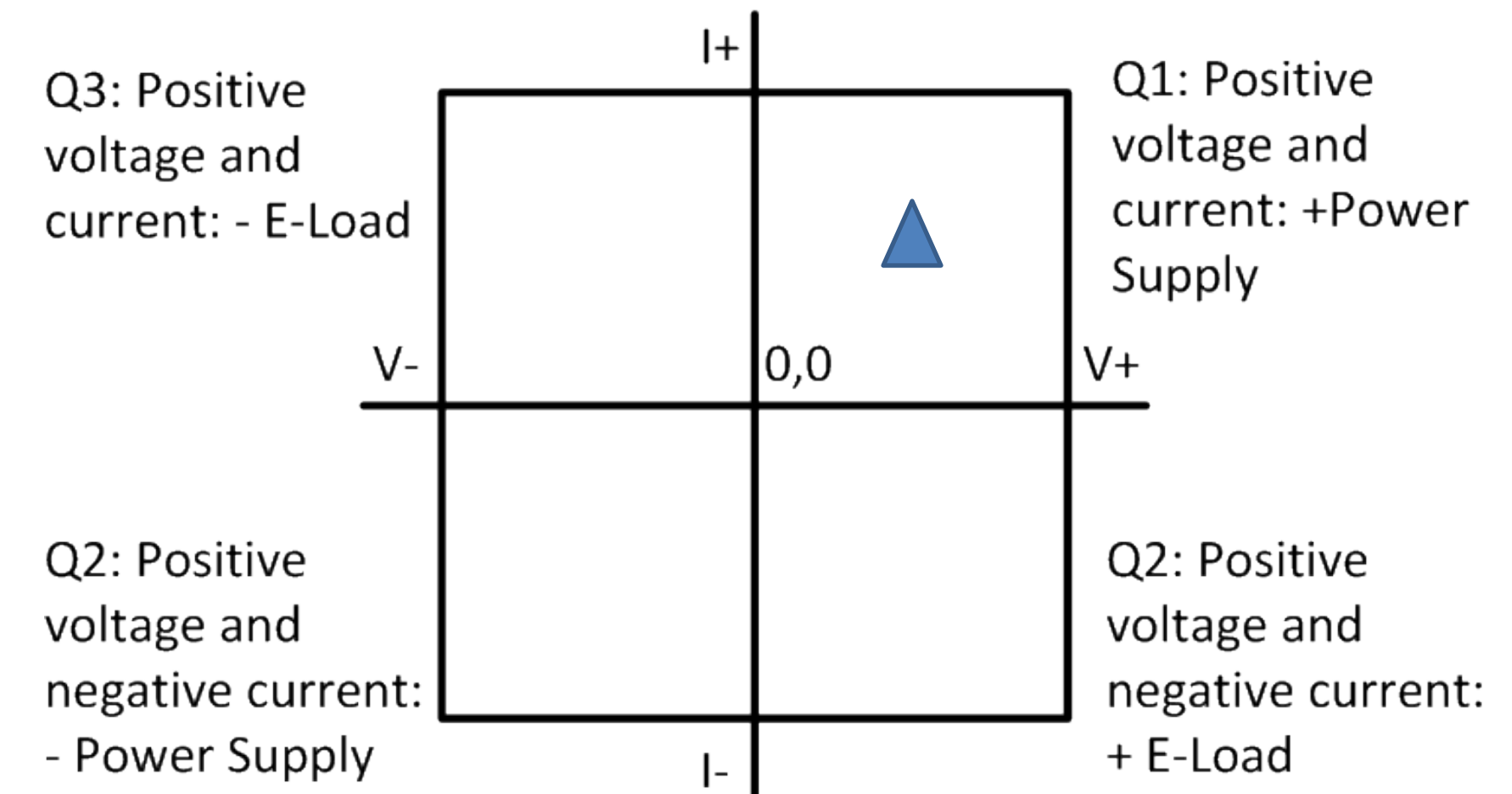
## DC power supply Control loop modulation

- Control Loop Modulation.
- Leadless remote sensing.
- Geschikt voor batterij emulatie.
- Dynamische belasting → frequentie response.
- Modulatie kan worden geïntroduceerd in de regellus door een variabele op te tellen bij de setpoint-waarde of door beide met elkaar te vermenigvuldigen.

Control ingang	Functietype	
	0	1
1	$V_o = G_v [V_{ref} \times \text{Mod}(V_{MOD})]$	$V_o = G_v [V_{ref} + \text{Mod}(V_{MOD})]$
2	$I_o = G_l [I_{ref} \times \text{Mod}(V_{MOD})]$	$I_o = G_l [I_{ref} + \text{Mod}(V_{MOD})]$



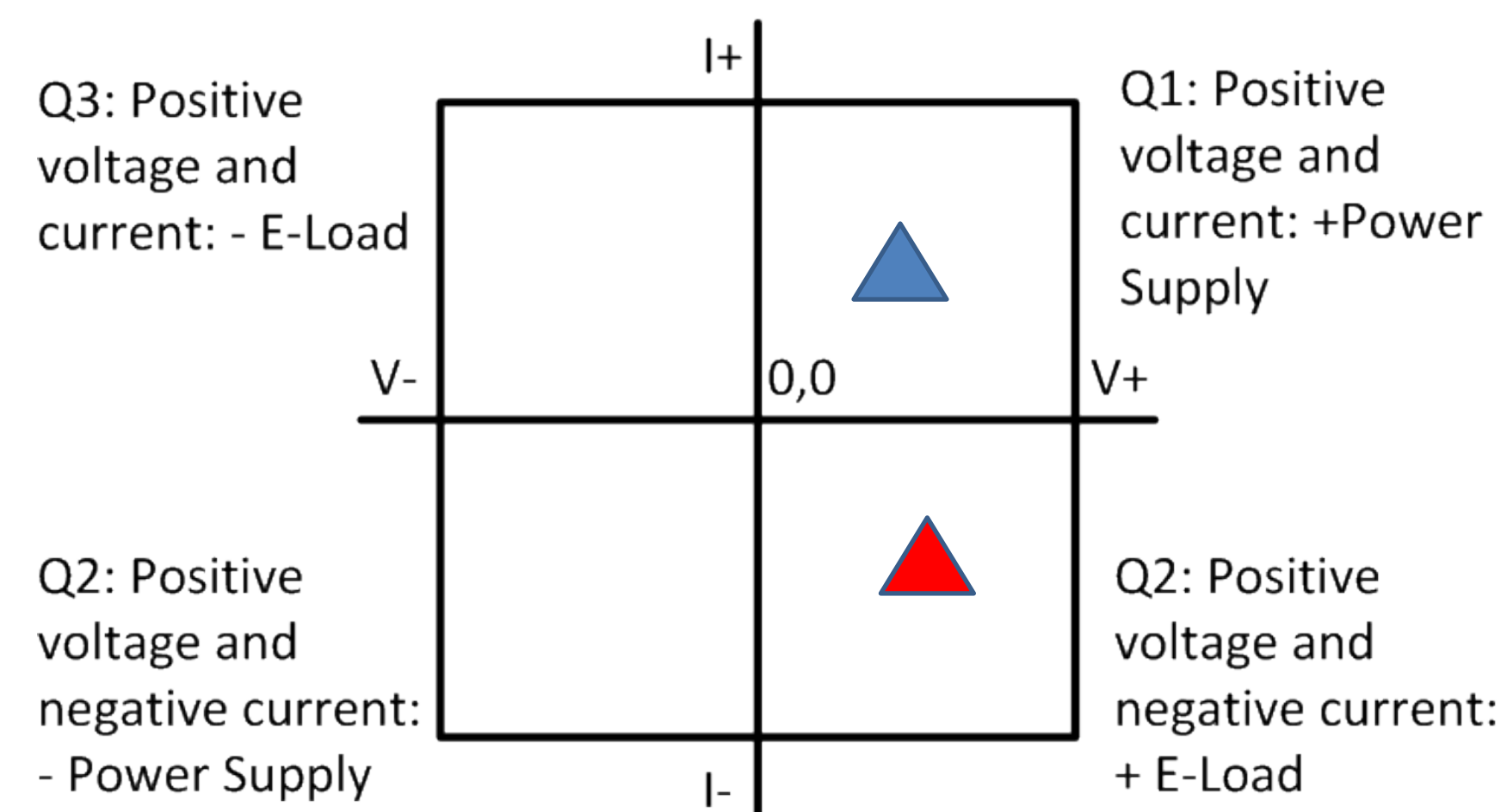
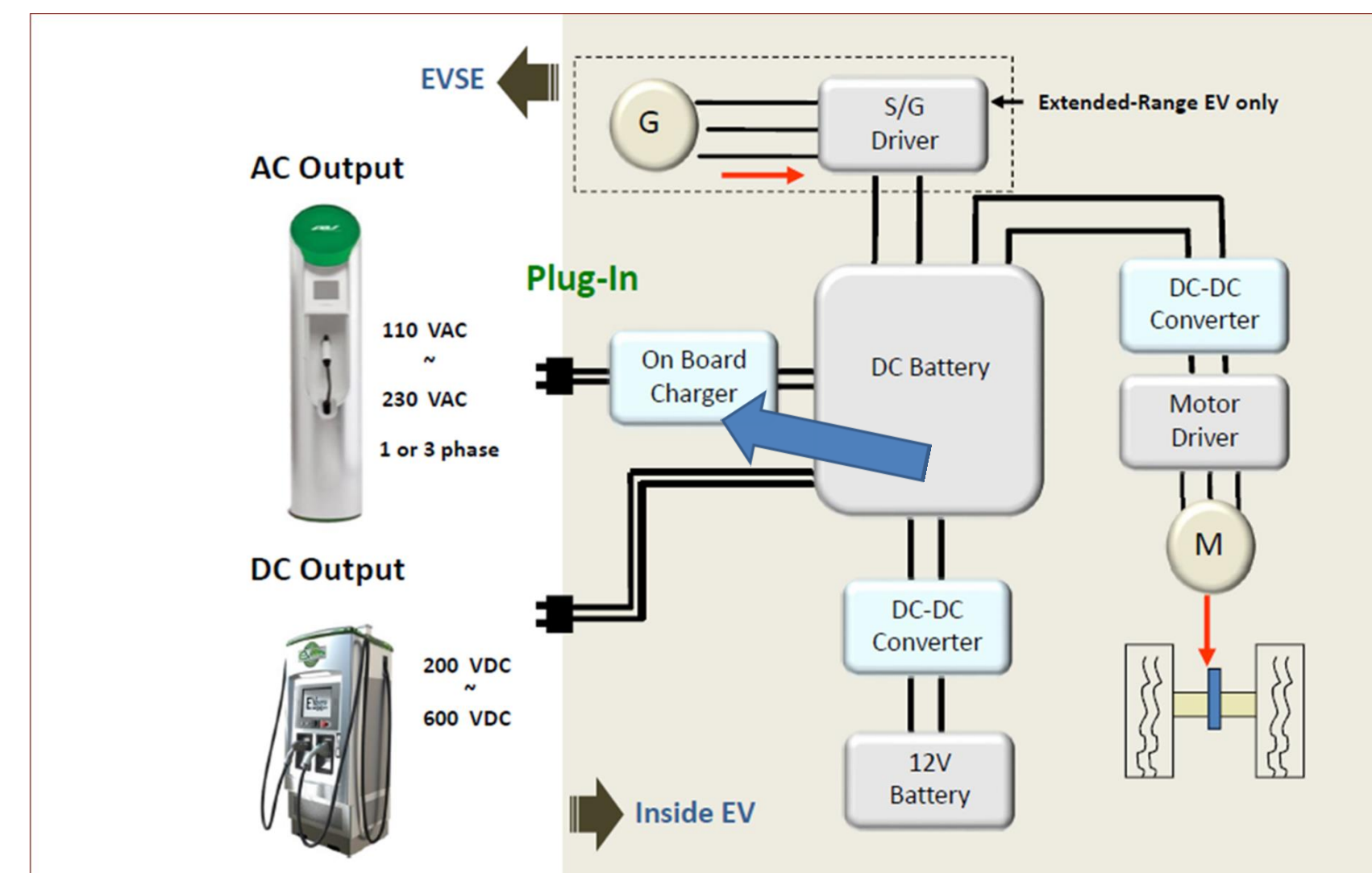
Figuur 1. Blokschema van een voeding met modulatie.



# Batterij Emulatie: Praktische oplossingen

## DC power supply Ri instelbaar

- Programmeerbare output impedantie.
- Ingebouwde functie voor instellen Ri.
- Battery laad- / ontladtesten.
- Simulatie van batterij wordt benaderd.
- Beperkte 2 kwadrant functionaliteit.

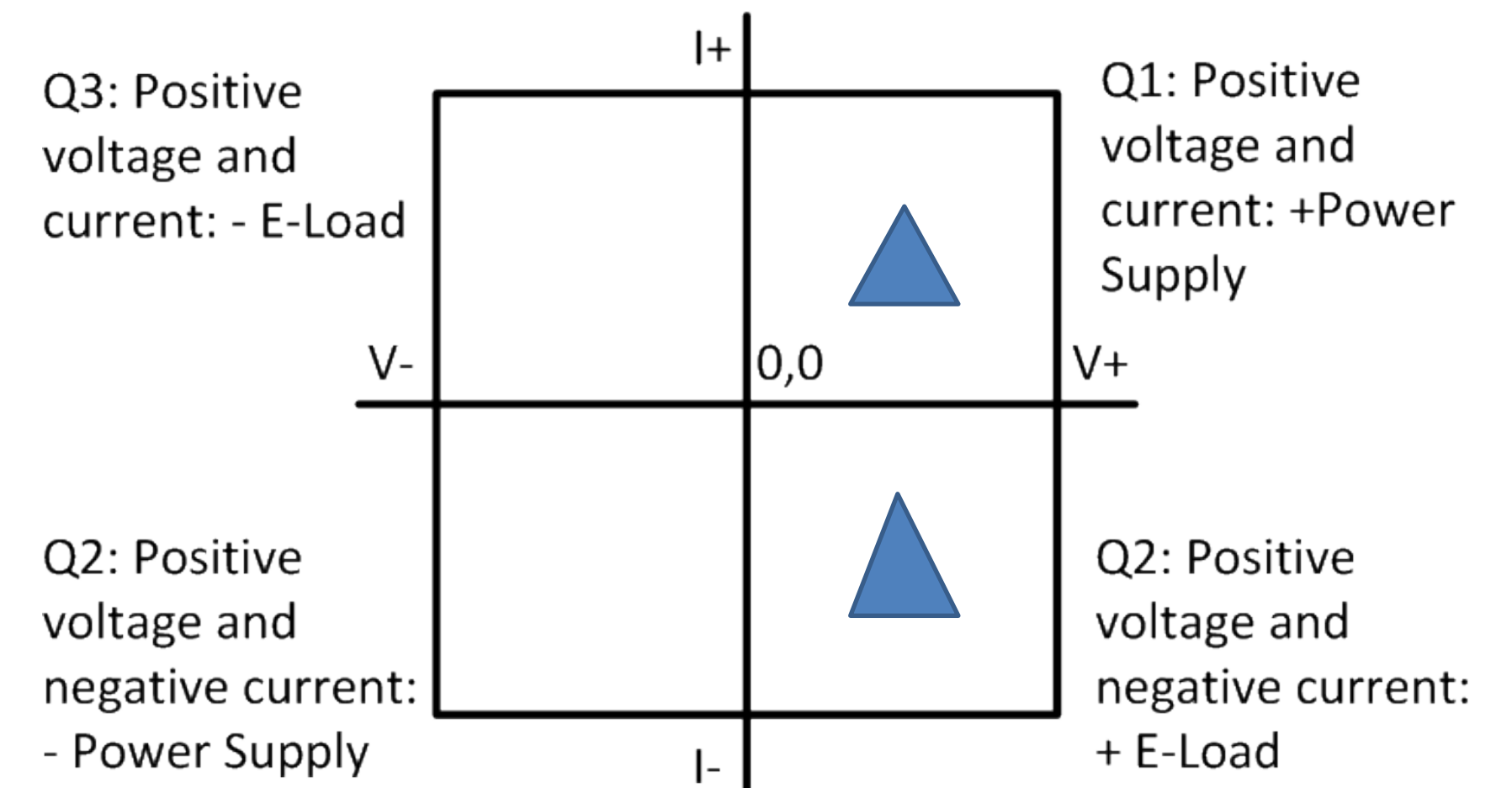
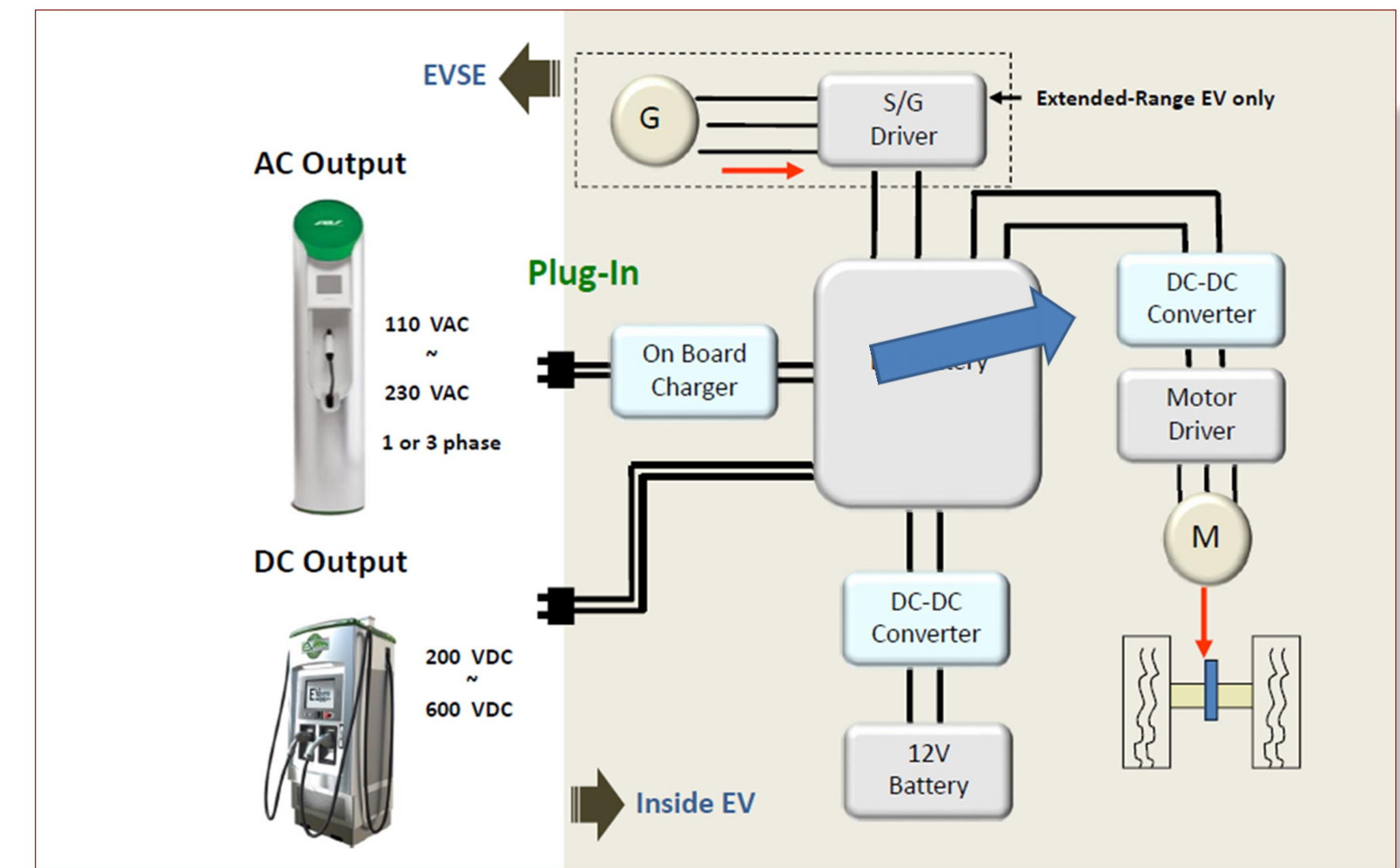
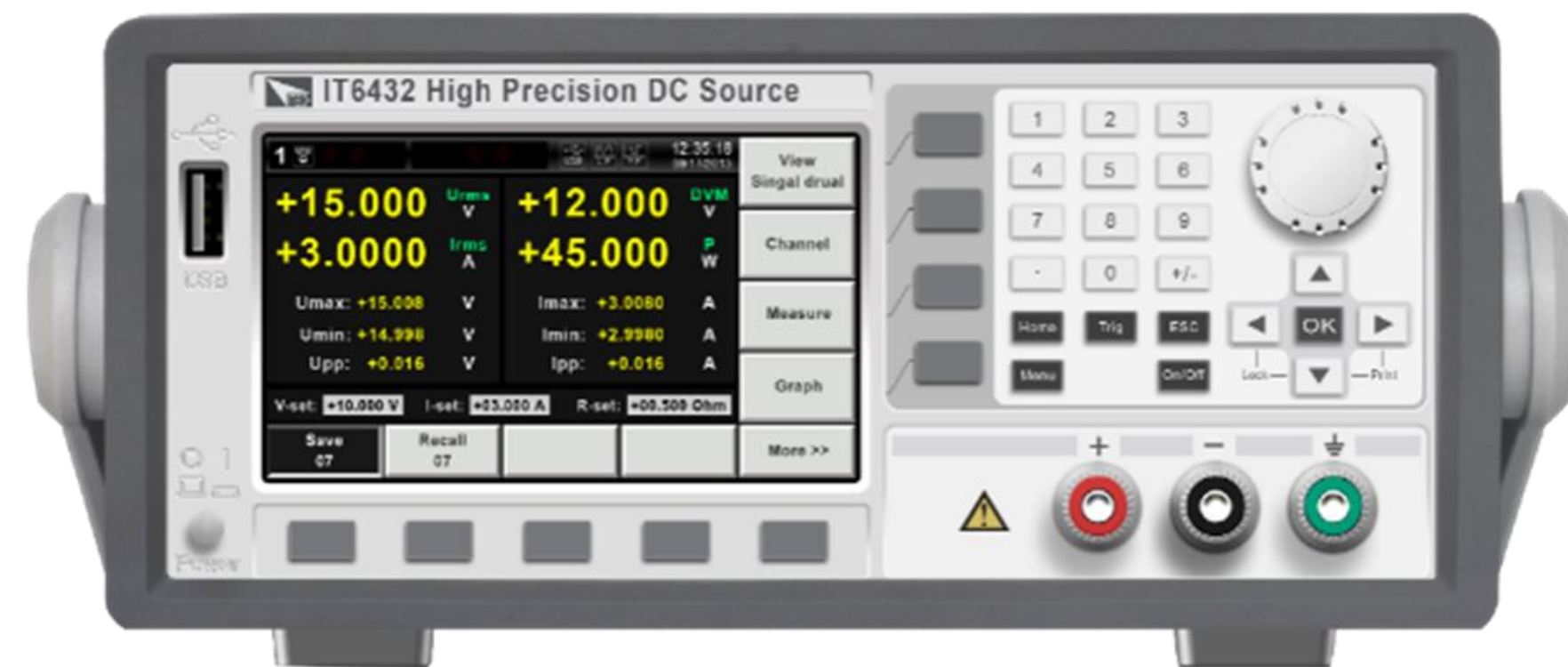


# Batterij Emulatie: Praktische oplossingen

## Bipolair DC Power Supply

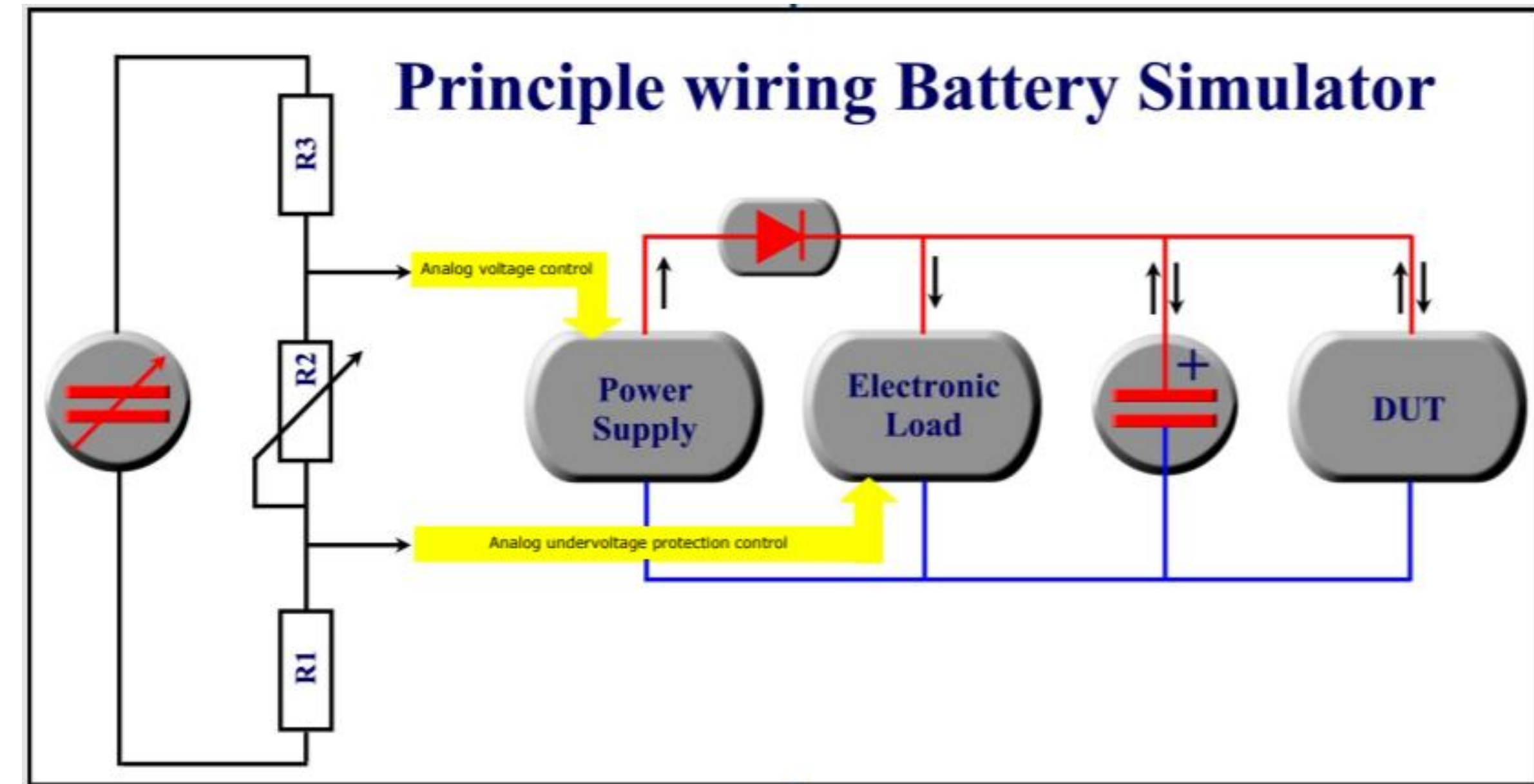
Voorbeeld bipolair power supply:

- Bipolair ontwerp / Transient Time  $< 20 \mu\text{s}$ .
- Batterij simulatiefuncties.
- $0 \sim 20 \Omega$  variable output impedantie.
- Simulatie battery charge-discharge functies.



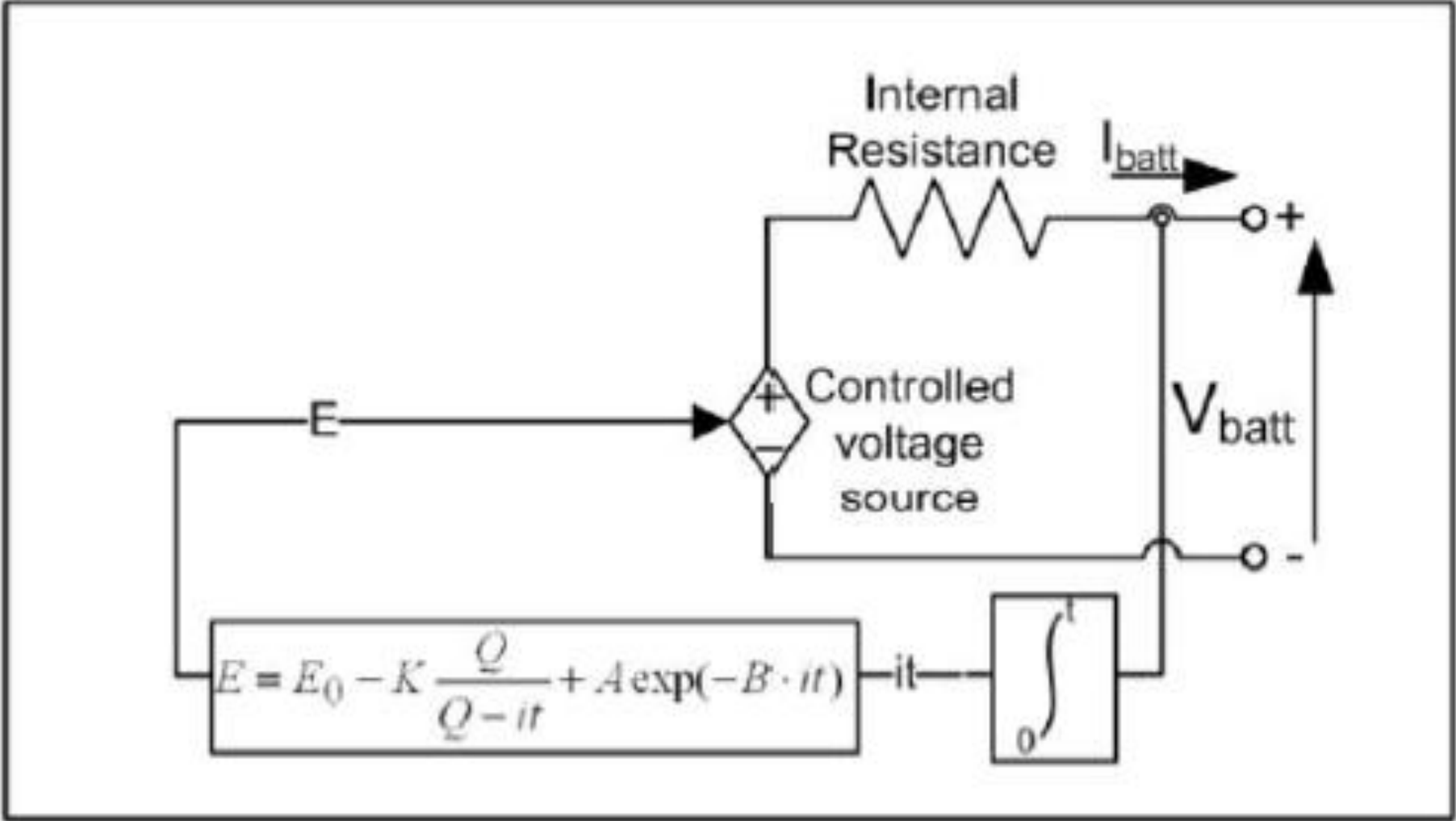
# Batterij Emulatie: Praktische oplossingen

- 2 kwadrant oplossing.
- Combinatie power supply en een elektronische belasting.
- De power supply is parallel geschakeld met de elektronische belasting via een decoupling diode.
- Eventueel een buffer condensator.
- Via een analoge regeling zijn naast de gewenste spanning ook over en onder voltage te definiëren.

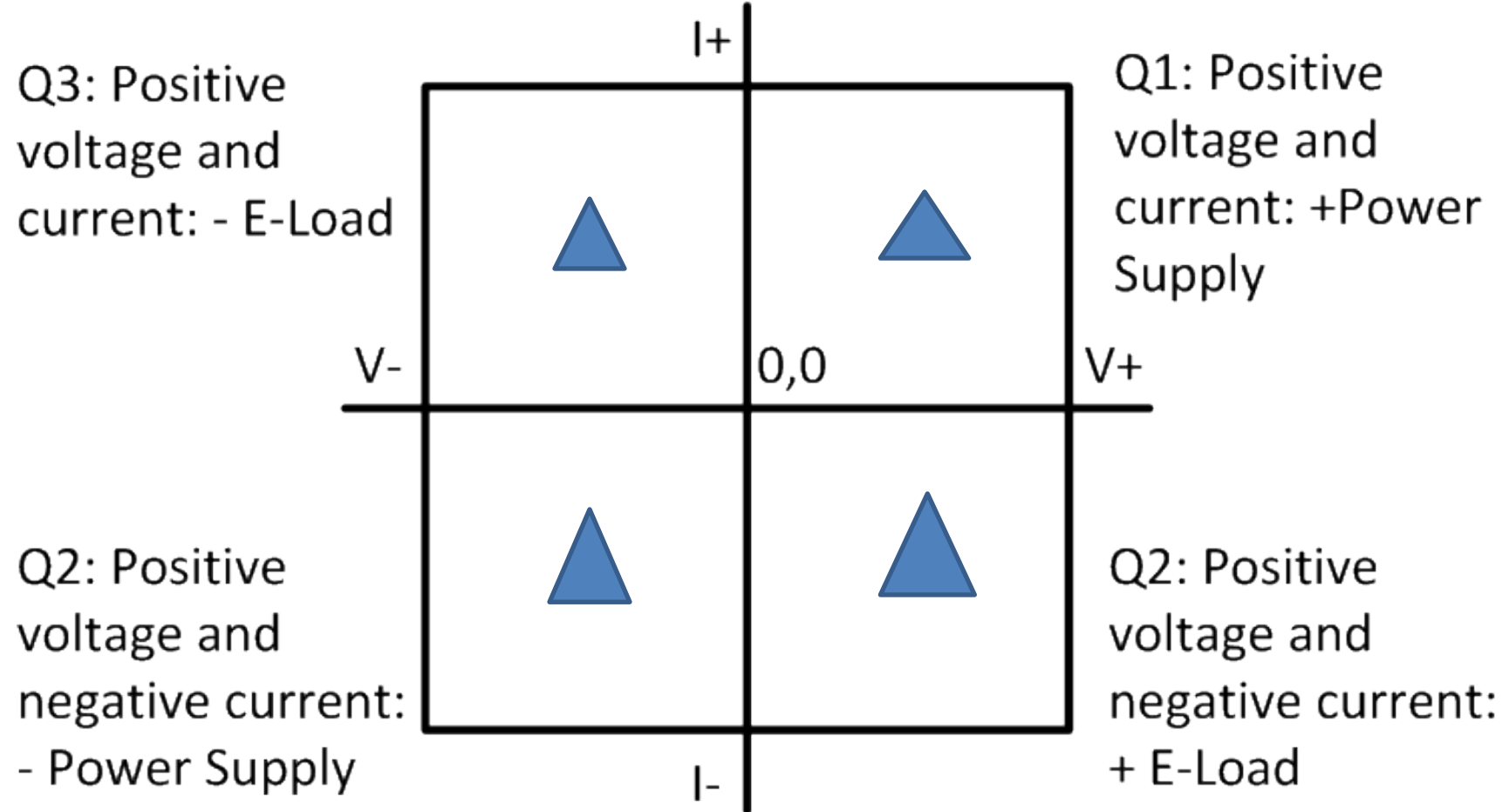
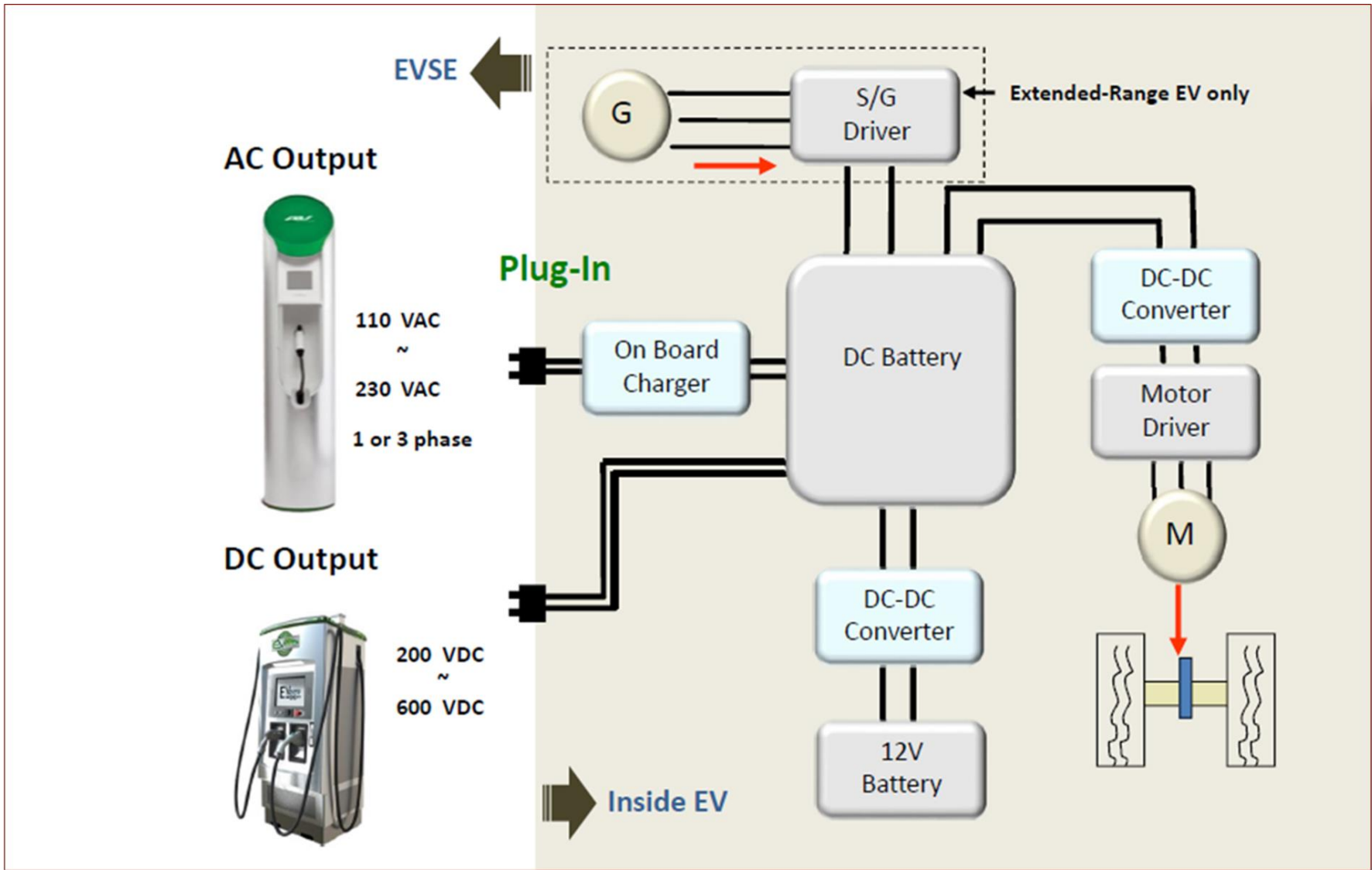


# Batterij Emulatie: Praktische oplossingen

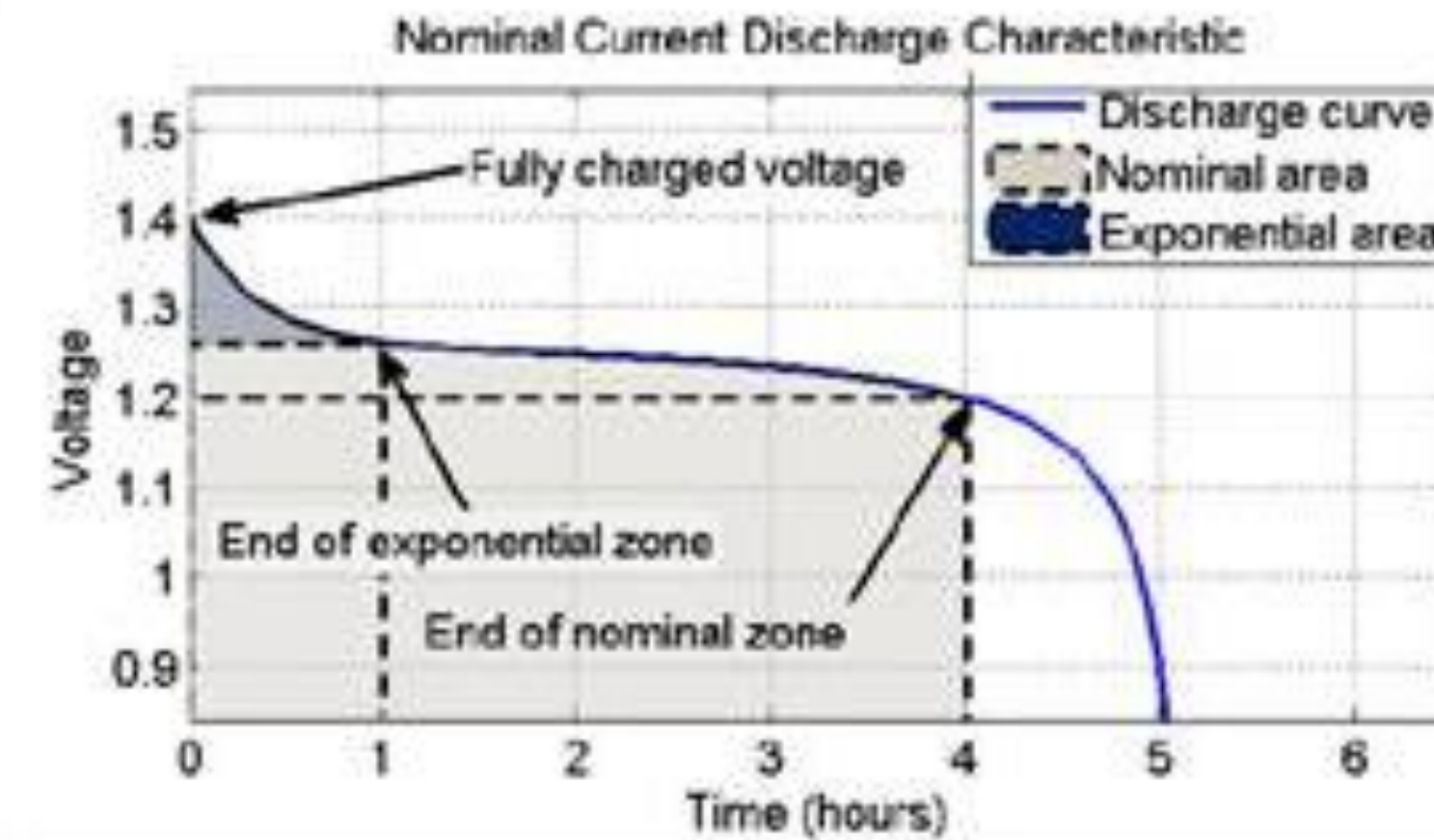
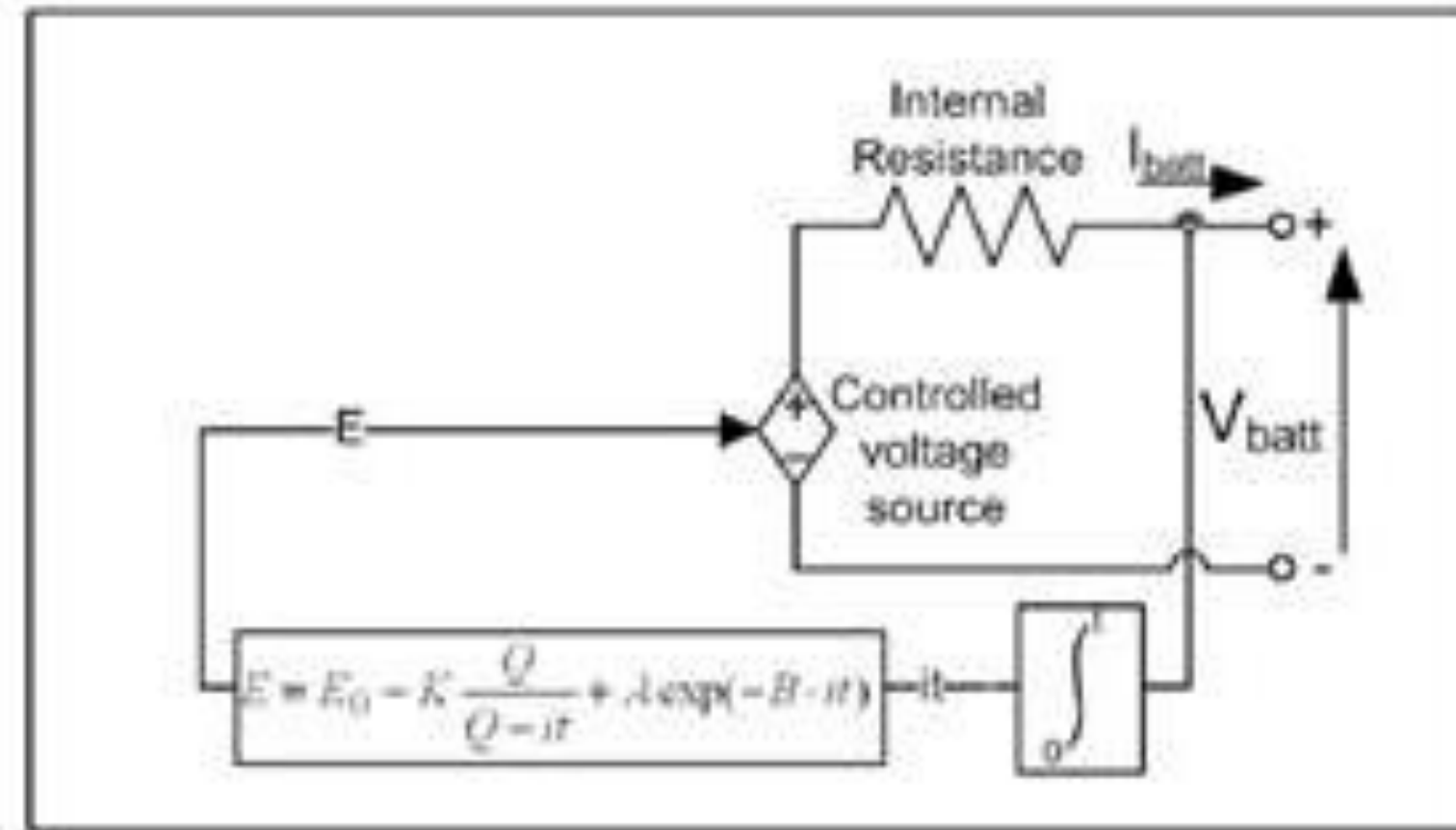
## DC power supply Emulatie volgens Mathematical model



Model and picture above are from: O. Tremblay, L.-A. Dessaint, A.-I. Dekkiche, "A Generic Battery Model for the Dynamic Simulation of Hybrid Electric Vehicles", 2007 IEEE® Vehicle Power and Propulsion Conference, September 9-13, 2007, Arlington/Texas, USA



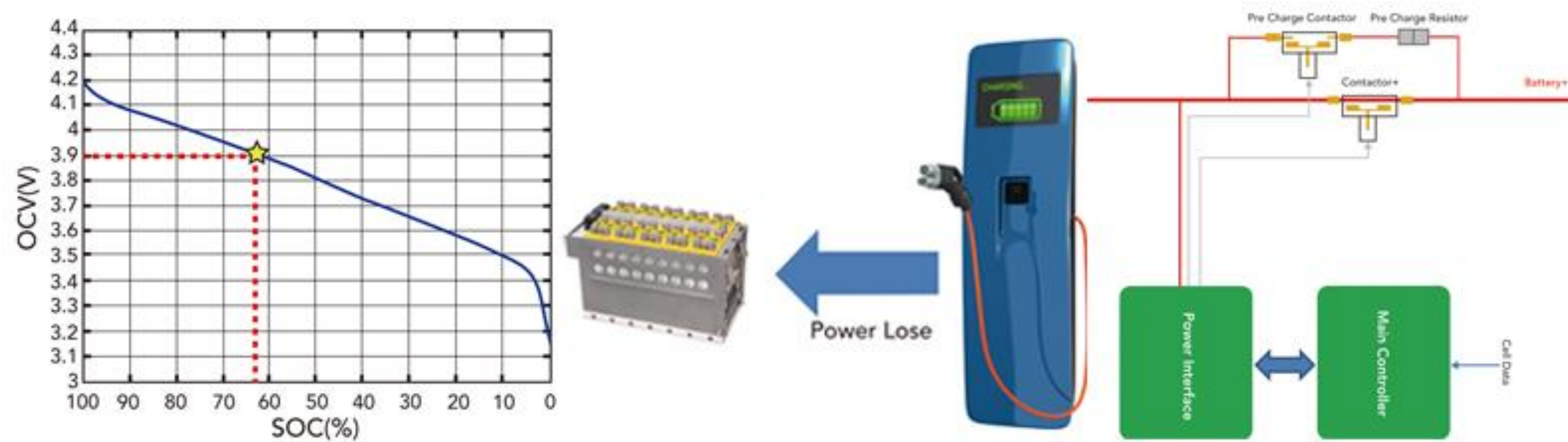
# Batterij Emulatie: Praktische oplossingen



BATTERY PARAMETERS

Type	Lead-Acid	Nickel-Cadmium	Lithium-Ion	Nickel-Metal-Hydrid
Parameters	12V 1.2Ah	1.2V 1.3Ah	3.6V 1Ah	1.2V 6.5Ah
$E_0(V)$	12.6463	1.2505	3.7348	1.2848
$R(\Omega)$	0.25	0.023	0.09	0.0046
$K(V)$	0.33	0.00852	0.00876	0.01875
$A(V)$	0.66	0.144	0.468	0.144
$B(Ah)^{-1}$	2884.61	5.7692	3.5294	2.3077

# Batterij Emulatie: Praktische oplossingen



## Initial output state setting

- Snelle programmering naar elke gewenste setting.
- Geen wachttijden tot “echte” batterij is geladen / ontladen tot gewenst setpoint.
- Diverse applicatie software.



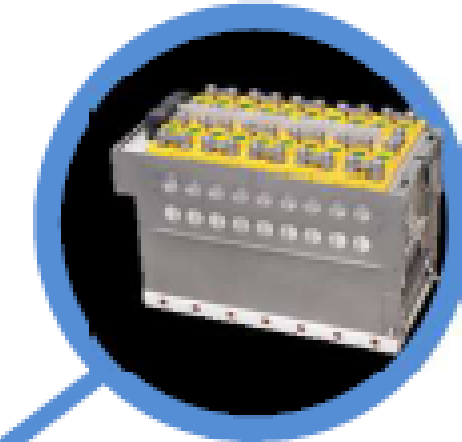
## Key Features

- Volgt de batterijcurve, gedraagt zich als zodanig en simuleert de batterijstatus.
- Programmering van veelgebruikte parameters om snel de juiste output stage te kunnen definiëren.
- Regeneratieve battery energy discharge functie, power saving.
- Meerdere units / uitgangen parallel schakelen voor hogere stromen.
- Operating mode: Constant Current/Constant Voltage/Constant Power discharge  
Dynamic current charge and discharge simulation.

# Batterij Emulatie: Praktische oplossingen

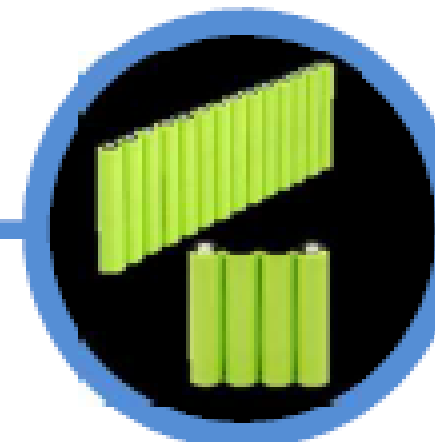


## Battery Simulator Soft-panel



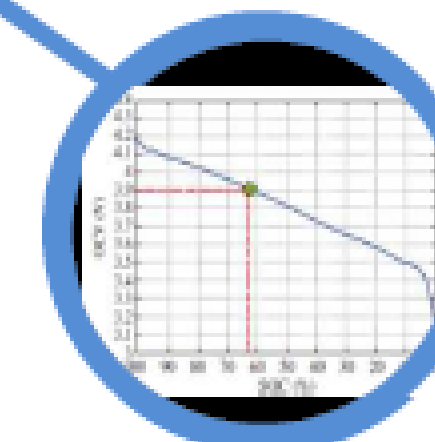
### Initial Condition

- Initial Output
- Eff setting
- Pre Charge Function



### Battery Pack Configuration

- battery cell in Series/ Parallel
- Battery impedance
- Battery Operation / Protection



### Battery conditions

- Curve Input
- Battery Parameter
- CHG/DSG Method

# Batterij Emulatie: Praktische oplossingen



## 1 - Voltage Constant.

This voltage is normally given by the manufacturer of the battery.

## 2- Exp Amp.

It is the voltage that will be increased from the Voltage Constant depending on the technology of the battery.

## 3- K Polarisation.

This parameter describes the slope of the left.

## 4- B Exp Time.

It describes how long the horizontal part of the line in the graph will be.

## 5 - Q Capacity.

Capacity of the battery in Ah.

## 6 - Virtual Resistance.

This resistance is also delivered by the manufacturer of the battery

# Batterij Emulatie: Praktische oplossingen

## Battery conditions setting

### (1) Battery Pack Configuration

- Set battery pack in Series/ Parallel



### (2) Battery Pack Configuration

- Equivalent Resistor = Cell impedance
- Other Resistor = PCBA + Cable...etc.



### (3) Battery Pack Operation / Protection

- $VH/100\% = SOC\ 100\%$
- $VL/0\% = SOC\ 0\%$
- $VOH/BOH = SOC > 100\%$  (OVP)
- $VOH/BOH = SOC < 0\%$  (UVP)
- $BVH/BCH = SOC\ 80\%$  (Operating area high)
- $BVL/BCL = SOC\ 20\%$  (Operating area Low)

### Battery Information

▼ Pack Configuration

Core Pack  
 Series(S)  Parallel(P)

DCIR  
 $0.005 + DCR\ 0.01 = 0.015\ (\Omega)$

Voltage at 100% SOC(V)

Voltage at 0% SOC(V)

Capacity(AH)

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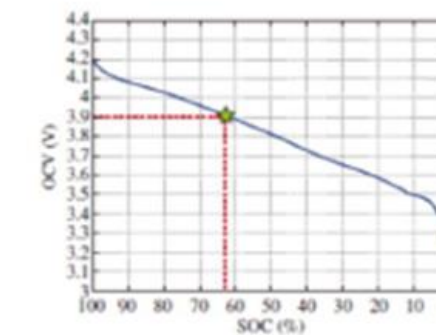
▼ Protection Configuration

	SOC	OCV
BOH%	<input type="text" value="110"/>	VOH(V) <input type="text" value="56"/>
BOL%	<input type="text" value="-10"/>	VOL(V) <input type="text" value="16.4"/>
BCH%	<input type="text" value="105"/>	BVH(V) <input type="text" value="4.28"/>
BCL%	<input type="text" value="-5"/>	BVL(V) <input type="text" value="2.8"/>

## Battery conditions setting

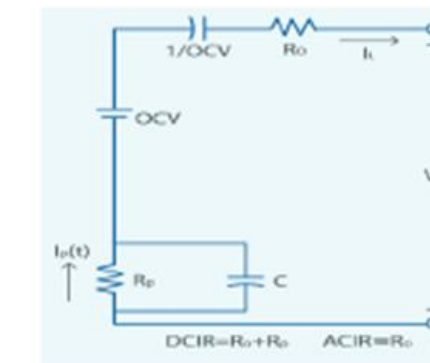
### (1) Curve Input

- Basic Curve (straight line)
- VOLT vs SOC Curve
- VOLT vs Ah Curve



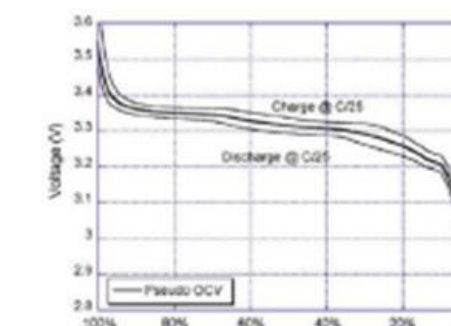
### (2) Battery Parameter

- $R_o$
- Capacity



### (3) CHG/DSG Method

- Charge Curve
- Discharge Curve



### Curve Process Setting

Curve 1 | Curve 2 | Curve 3 | Curve 4

OCV vs Capacity  
 Basic  
 OCV vs SOC

Battery Curve Filename

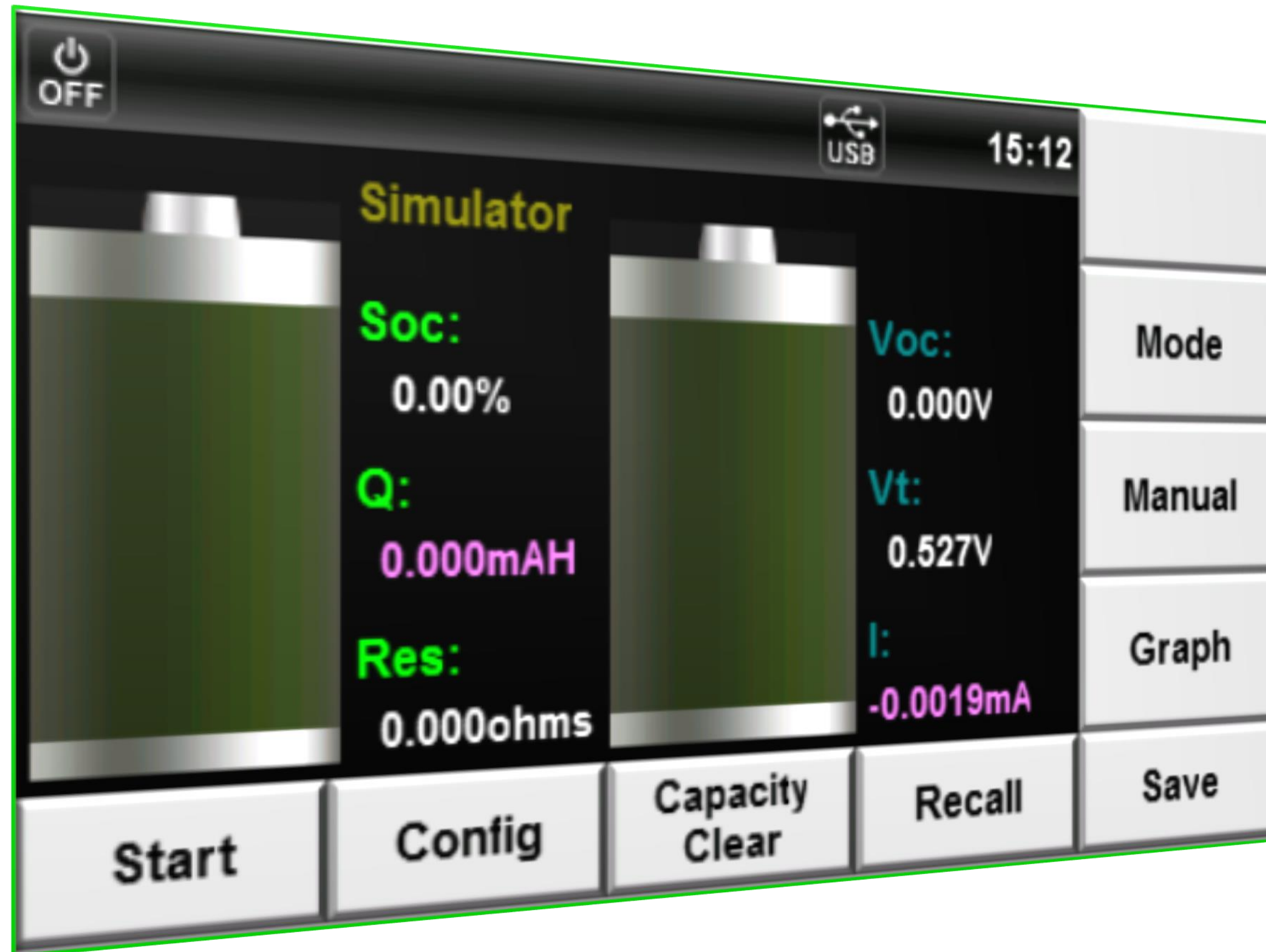
Cycle Times(time)

DCR( $\Omega$ )  Total Capacity

Current(A)  Data Number

Cut-off Condition  
 SOC(%)  Capacity(Ah)

# Batterij Emulatie: Praktische oplossingen

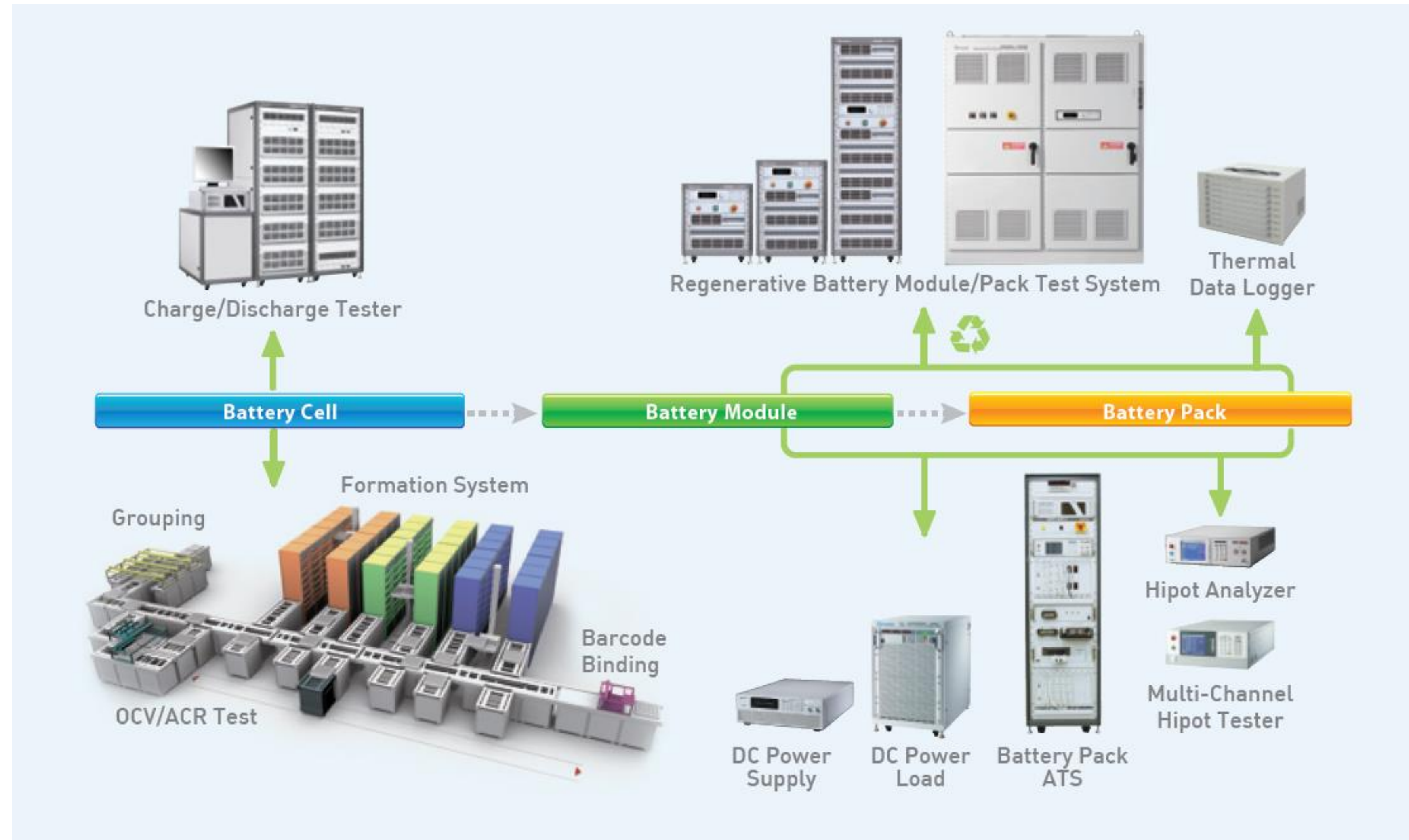


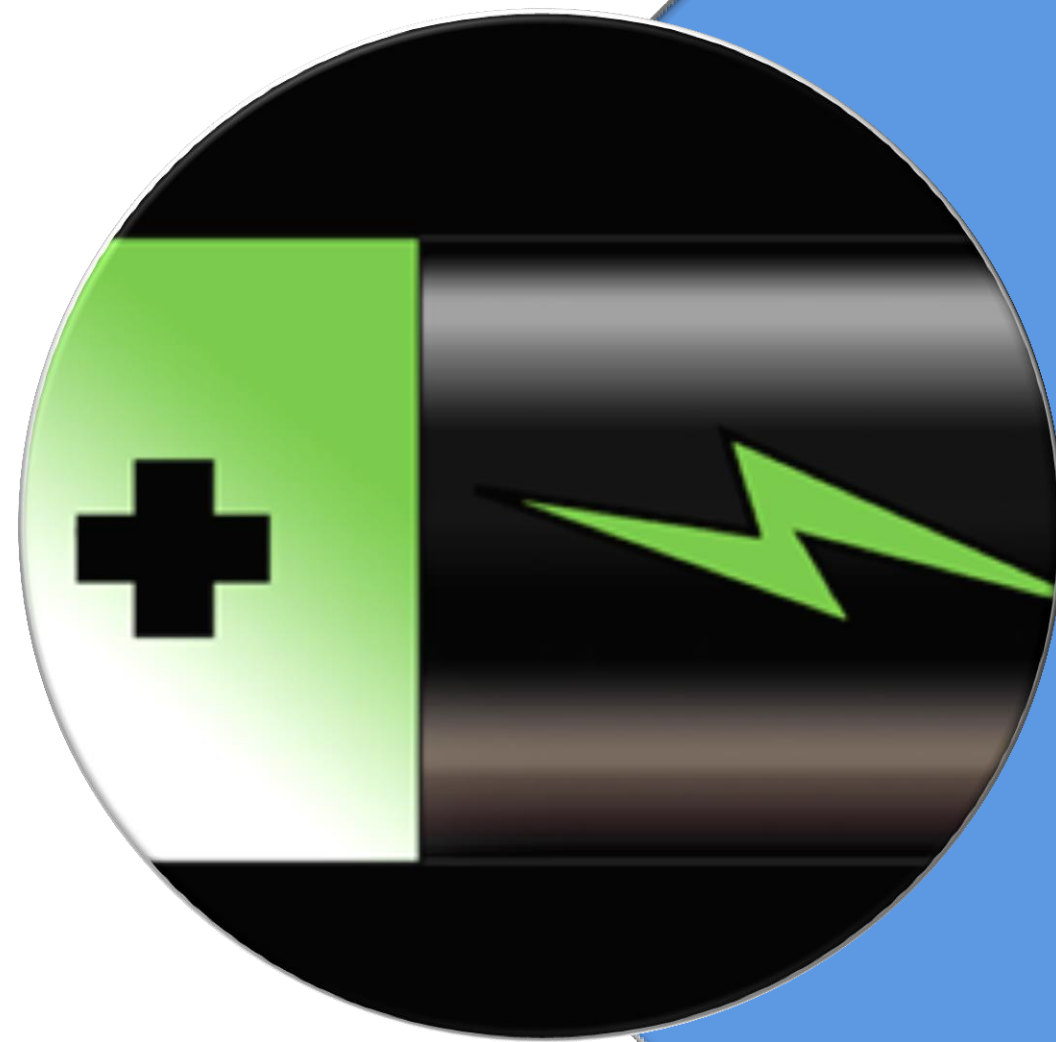
## Main Features:

- Simulate real battery output, with the maximum current of 10 A sourcing and sinking
- Program the battery SOC and Equivalent Series Resistance and Voc
- Output according the battery model and be set arbitrary initial state to accelerate the charge/discharge test
- Monitor main battery parameters in graphical user interface
- With the help of IT9000 software, it can record voltage, current, capacity with time

## BATTERIJTESTEN

- Charge / discharge
- DCR / ACR
- Cycle testing
- Impedance analysis
- Safety testing





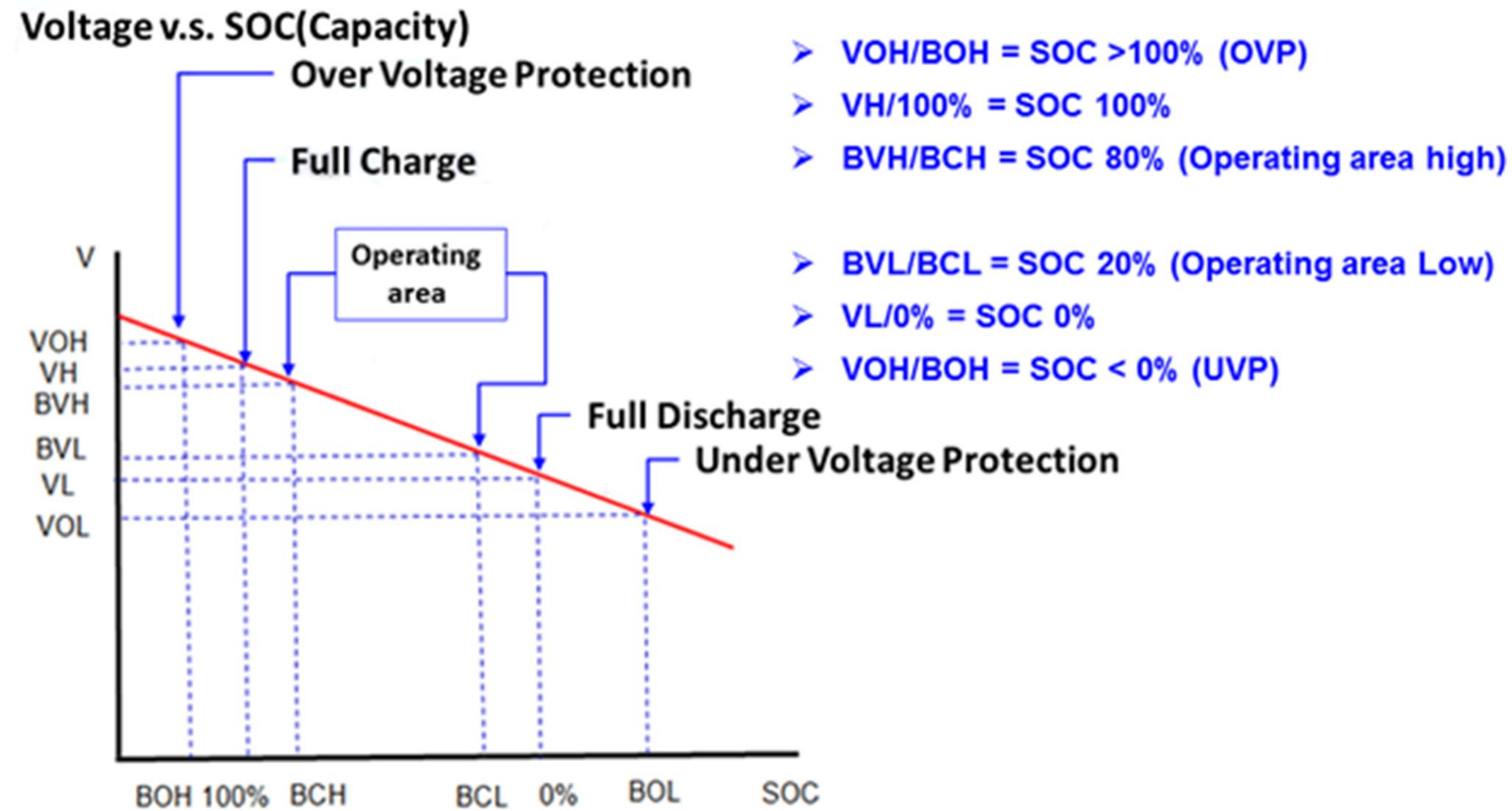
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# Batterij Emulatie

## Conclusie / afsluiting



- Flexibiliteit
- Reproduceerbaarheid
- Programmeerbaar
- Reductie in test-/ evaluatietijd

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**ELECTRONICS**

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Bedankt voor uw aandacht!

Zijn er nog vragen?

