前瞻電池研究與測試技術交流平台

Advanced Battery Research And Testing Techniques Co-operative Alliance

研發 → 回收
動力電池生命週期 2016 應用論壇

From Research to Recycle: the Life Cycle of EV Batteries Seminar

主辦單位：承德科技股份有限公司
時　　間：2016年10月14日(星期五) 13:00 - 17:00
地　　點：北科大 集思會議中心 西特廳 204會議室
(台北市忠孝東路三段193巷旁 台北科技大學 億光大樓2樓)

cte 承德科技 CHEN TECH ELECTRIC

前瞻電池研究 & 測試技術交流平台

從研發到回收-動力電池生命週期應用論壇

2016 年 10 月 14日

議程時間

時間 Time	主題 Subject	主講 Speaker
13:00~13:30	報到與交流 Registration	
13:30~13:40	引言 Introduction	承德科技 周志勳 副總經理暨技術長 Dr. Anthony Chou, Vice President & Chief Technology Officer at Chen Tech Electric
13:40~15:00	高功率電動車電池組測試解決方案 High Power EV Battery Pack Test Solution	Gustav Klein (GK) Michael Reith經理 Mr. Michael Reith, Sales Manager at Gustav Klein GmbH & Co KG 承德科技 林呈融 經理 Mr. Curtis Lin, Product Manager at Chen Tech Electric
15:00~15:40	PBT 1000 Demo與茶敘 PBT 1000 Demo & Coffee Break	
15:40~16:20	電動車汰役電池測試相關標準介紹 International Standards of Used EV Batteries Test	優力國際安全認證有限公司 陳立閔 經理 Mr. Benjamin Chen, Business Development Manager at UL Taiwan
16:20~17:00	承德科技SOH解決方案介紹 CTE's State of Health(SOH) Evaluation Solution	承德科技 黃彥銘 研究專員 Mr. YM Huang, Research Scientist at Chen Tech Electric

尊重講者及與會人員權益，請您將手機調為靜音，謝謝！

High Power EV Battery Test Solution

Part 1: GK's experiences working with European automotive manufacturers

Part 2: PBT 1000 Series (ITS system) hardware and feature introduction

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Technology & Innovation

Competence & Experience

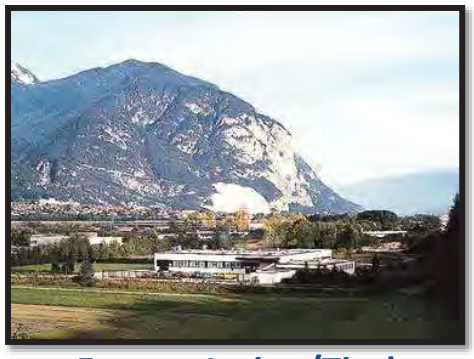
Quality & Reliability

Your Partner for all aspects of power supply equipment - worldwide

Power Supply Solutions

"... made in Germany & Austria"

Factory Schongau
approx. 160 employees



Factory Inzing/Tirol
approx. 60 employees

milestones:

1948 Foundation GK Schongau

1969 Foundation GK Inzing

1970 first switch mode units

1996 IGBT UPS

1997 first mains backing system with battery storage

2007 battery simulation 10 ... 1000 V 800 kW

2010 expansion Greifenstraße

2013 expansion GK Schongau

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Innovations, Awards, Prices

100 Innovative small firm sector Germany :
Cachet Top 100

Awarded companies with high economic, social, technological and environmental benefits:
Predicate BEST OF

Hessian State Price for intelligent Energy:
category Energy-IKT - SEM Smart Energy Award 2012

Initiative small firm sector:
category Innovation award-IT – certificate Best of 2012

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Actual Target Markets

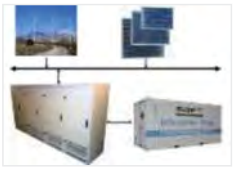
Test- and Simulation systems

Power stations and Power lines

Stationary power supply for urban traffic and railway lines

Operation theaters

Chemical Industry / oil and gas



High power storage systems

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

References Industry Sector

DB BAHN
ÖBB
SIEMENS
DALE POWER SOLUTIONS
OMV
SSB
RHEIN PAPIER
ALCATEL
THALES
Deutsche Telekom
Balfour Beatty
KVB
SPITZKE EUROPEAN CLASS
HENSEL PASSION FOR POWER.
degussa.
BOMBARDIER TRANSPORTATION
VAG Überlegen bewegen.
Lurgi
ABB
steag
EnBW
THE LINDE GROUP
GAZPROM
e·on
sappi
WIENER LINIEN
ThyssenKrupp
VORWEG GEHEN
VELTINS
PINTSCH TIEFENBACH
Verbund
TELEKOM AUSTRIA
mtu
tiroler wasserkraft
wintershall
HITACHI Inspire the Next
BASF We create chemistry
VATECH

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

References R&D sector

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Partner companies

EUROPA

ASIA

France
Equipment Scientifiques
Italy
DELO Instruments srl
Great Britain
Dale Power Solutions Ltd.
Ireland & Great Britain
ETPS Limited
Netherlands
e-Power
Netherlands & Belgium & Luxembourg
ar Benelux B.V.

Switzerland
UPSMeier Power Systems AG
Bulgaria
Stratex
Bulgaria
Valbis Trade Ltd.
Bulgaria
NRG Source Ltd.
Serbia
Enelps d.o.o.
Czech Republic
IBG Praha s.r.o.

China
Beijing Balfour Technology
Hong kong
Full Link Technology
Thailand
CBC International Co. Ltd.
Korea
NeoScience
Taiwan
Chen Tech Electric
Indonesia
PT Guna Elektro
Singapure
Petracarbon

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Partner companies

RUSSIA

Russia
DISSOLT

MIDDLE EAST

Iran
Pars Kavir Arvand Co. P.K.C.
Oman
Trade Links and Services Co. LLC.
Qatar
KEMCO Trading Company
Saudi Arabia
Core Team Global
United Arab Emirates
Power Economy Middle East Co. LLC.

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

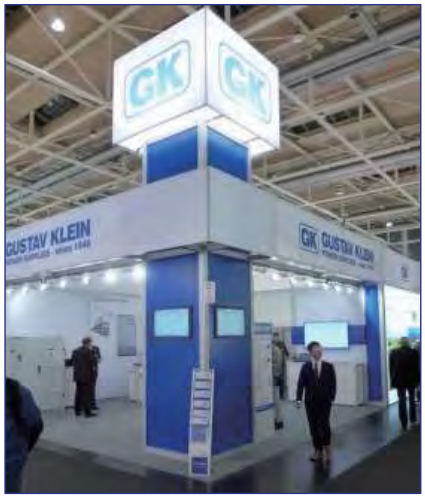
Certifications / Audits

TÜV SÜD : DIN EN ISO 9001
TÜV SÜD : DIN EN ISO 14001
Deutsche Bahn : Q1-Supplier
SIEMENS : Outstanding Supplier

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Fair program for 2016

WORLD FUTURE ENERGY SUMMIT
18-21 JANUARY 2016
ABU DHABI NATIONAL EXHIBITION CENTRE



ees
electrical energy storage
22. – 24.06.2016
München

ENERGY STORAGE EUROPE
15 -17 March 2016
Düsseldorf, Germany

electronica
November 8 - 11, 2016
Messe München

HANNOVER MESSE
25. – 29.04.2016

InnoTrans
Internationale Fachmesse für Verkehrstechnik
20.–23.09.2016
Berlin

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

High Power EV Battery Test Solution

Part 1: GK's experiences working with European automotive manufacturer

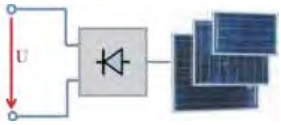
GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Products – DC-Source/ Sink – I-TS

Infeed Test System – power up to 1000 V/1000 A DC/AC

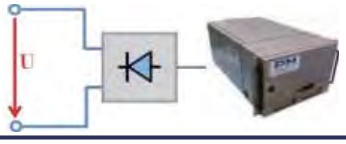
Inverter with wide input range for solar feeding

- Protection diode for safe sink operation



Inverter for fuell cell

- Protection diode for safe sink operation

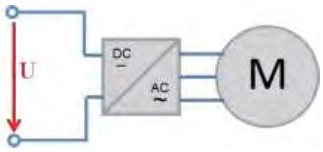


DC-Source / sink as battery-tester

- Current rise time < 1,5 ms (10 – 90 %)
- Output contactor for separation under load (optional)
- Current range switchable for smaller current range (optional)
- Increased accuracy up to 0,05 % with control software (BaSyTec)

DC-source / sink for battery simulation

- Regulation time < 2 ms (0 – 100 % load change)
- Optional protection of the DUT via discharge resistance



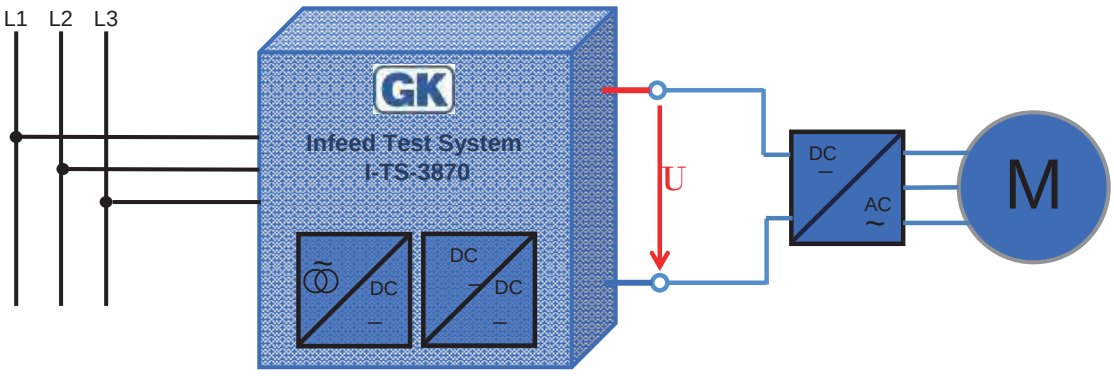
GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

I-TS as „Battery Simulator“

- Mode DC source and sink

Adaptation of the basic system

- Filter (increase in the capacity to stabilize the output voltage and reduction of the "ripple"
- Control ("U" voltage control)
- Stop function (safety controller opens the output contactors after a period of 5 sec)



GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

DC-Source / Sink for Battery Simulation

- To Test Electric Driven Accessories in Agriculture Technology

Darkking3 CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], via Wikimedia Commons

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

DC-Source / Sink for Battery Simulation

- To Test Inverter in Electric and Hybrid Vehicles

Von Norbert Aepli, Switzerland, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=24998132

Von RudolfSimon - Eigenes Werk, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=27357719

Von unbekanntFerrari S.p.A. - Eigene Vektorisierung, Logo, https://de.wikipedia.org/w/index.php?curid=3322356

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

DC-Source / Sink for Battery Simulation

- Formula 1: Testing KERS
  Kinetic Energy Recovery System

Von unbekannt Ferrari S.p.A. –
Eigene Vektorisierung, Logo,
https://de.wikipedia.org/w/index.php?curid=3322356

Von Magic Aviation - Ferrari F2013 - Fernando AlonsoUploaded by Dura-Ace, CC BY 2.0,
https://commons.wikimedia.org/w/index.php?curid=24765798

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

DC-Source / Sink for Battery Simulation

- Testing of Components, like Dashboards

By HLW (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

DC-Source / Sink for Battery Simulation

- Supply of Electronic Circuits of High Speed Trains during Maintenance

DB BAHN

Von Martin Lechler - Eigene Aufnahme mit Handy, Gemeinfrei, https://commons.wikimedia.org/w/index.php?curid=44976930

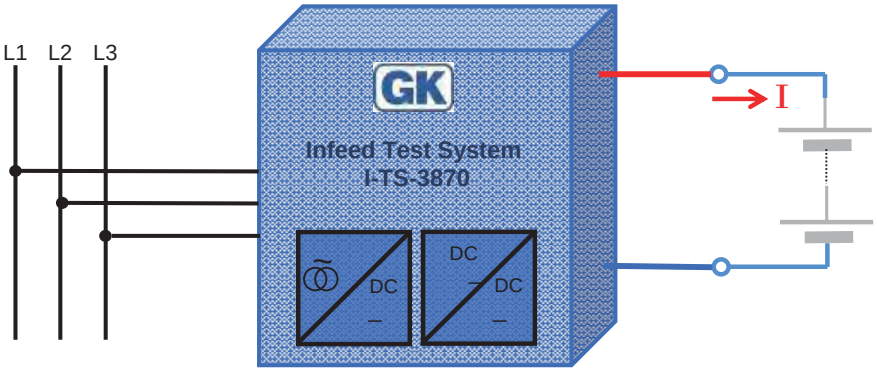
GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

I-TS as „Battery Tester“

- Mode DC-source and DC-sink

Adaptation of the basic system

- Control ("I +" and "I-" control)
- Stop function (safety controller opens the output contactors after a period of 0.5 sec)



GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

DC-Source / Sink as battery-tester

- Prototype Tesing of Li-Ion Batteries for Manufacturers of EV

KE-TEC GmbH

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

DC-Source / Sink as battery-tester

- Testing batteries for electric vertical takeoff and landing (VTOL) aircrafts

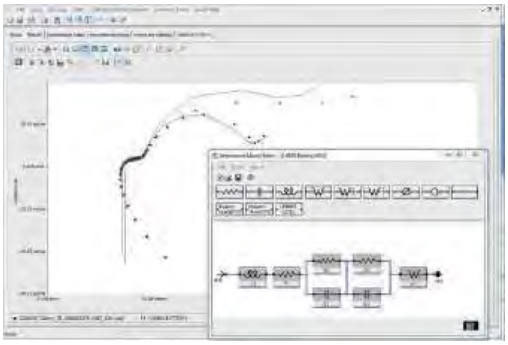
GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

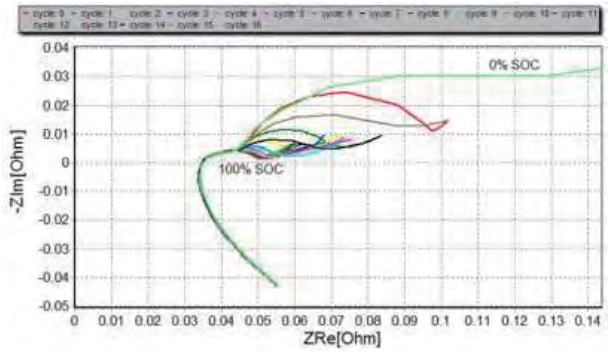
DC-Source / Sink as battery-tester

with BaSyTec EIS (Enhanced Impedance Spectroscopy)

Von Photograph taken by: Thomas Wolf (Der Wolf im Wald) Retouched by: LiveChocolate (Talk) - File:Audi e-tron.jpg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=9111586

- Modulation of AC voltage to DC Voltage and Current
- Measuring of AC Impedance
- Comparing with models of battery type
- Information about SOC (State of Charge) SOH (State of Health of battery)

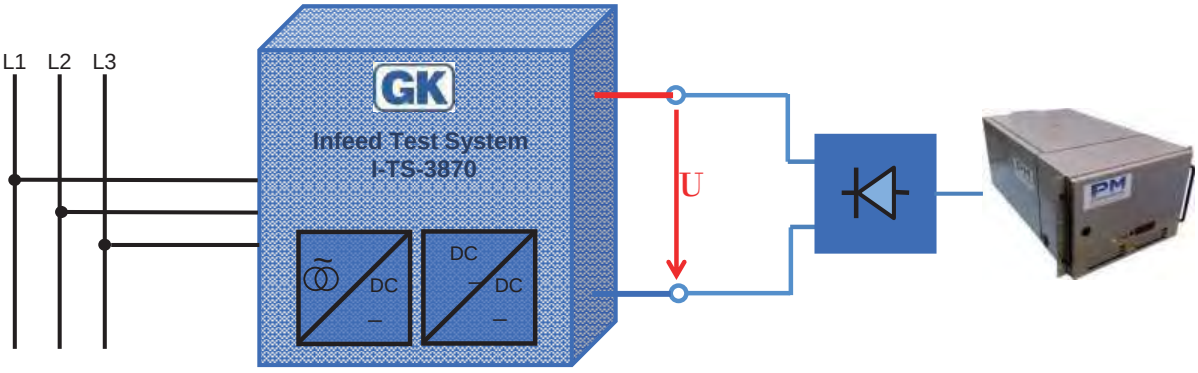




GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Inverter for Testing Fuel Cells

- Mode: inverter (DC-sink)



GUSTAV KLEIN
POWER SUPPLIES - since 1948

Inverter for Testing Fuel Cells

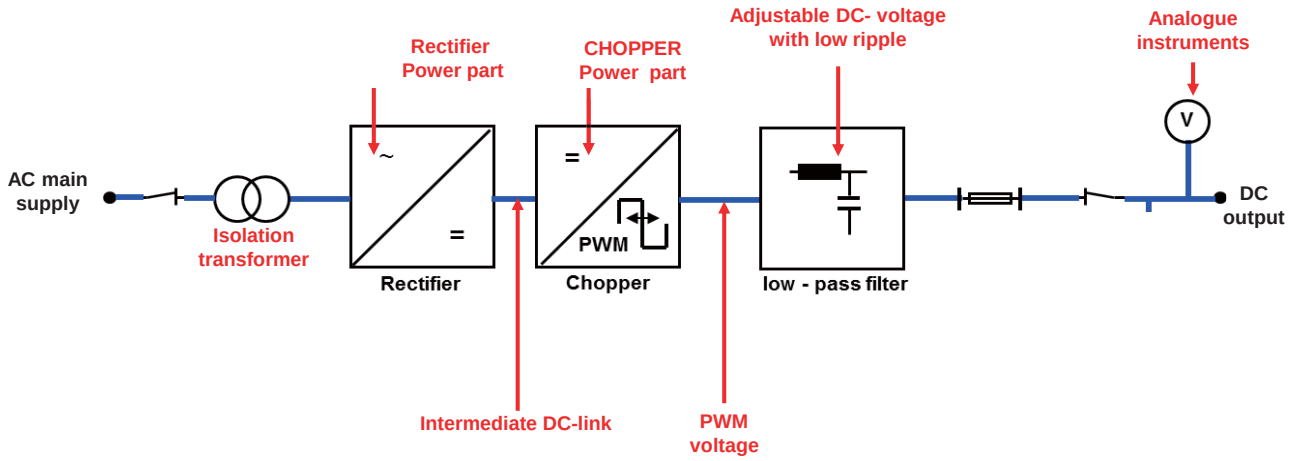
Bild: BMW

GUSTAV KLEIN
POWER SUPPLIES - since 1948

High Power EV Battery Test Solutions

Part 2: I-TS Hardware and Feature introduction

SLD of Infeed Test System



- Bi-directional DC power supply
  - High dynamic performance
  - High control accuracy

Field of Application

- Test stands and test facilities
  - DC supply for "battery testing"
  - DC supply for "battery simulation“
- High dynamic load in 2-quadrant operation for testing of:
  - Batteries (charging and discharging)
  - Inverters with wide input range for solar feed
  - DC electric motors
  - Fuel cells
  - Super capacitors

GUSTAV KLEIN
POWER SUPPLIES - since 1948

„Two major types of I-TS“

Battery Tester

- Output filter with lower capacitance
- Control mode: current
- Special feature:
  High dynamic in current change
- Current rise time of <1 msec (standard system 800V / 600A) (40 - 60% of the rated voltage)
- Current ripple <0.1% fs rms at Udc>10VDC

Battery Simulator

- Output filter with higher capacitance
- Control mode: voltage
- Special feature:
  Low voltage dip at current transients

GUSTAV KLEIN
POWER SUPPLIES - since 1948

Orginal Measured Curve „Battery Tester“

330 A / 600µF
(Basic unit equipment)

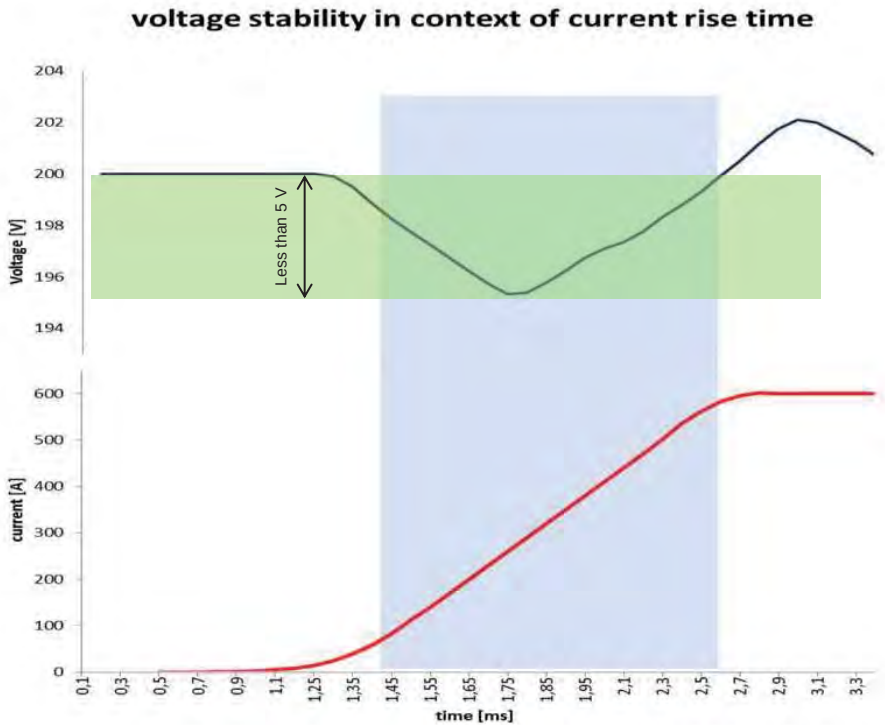
GUSTAV KLEIN
POWER SUPPLIES - since 1948

Orginal Measured Curve „Battery Simulator“

330 A / 7200µF

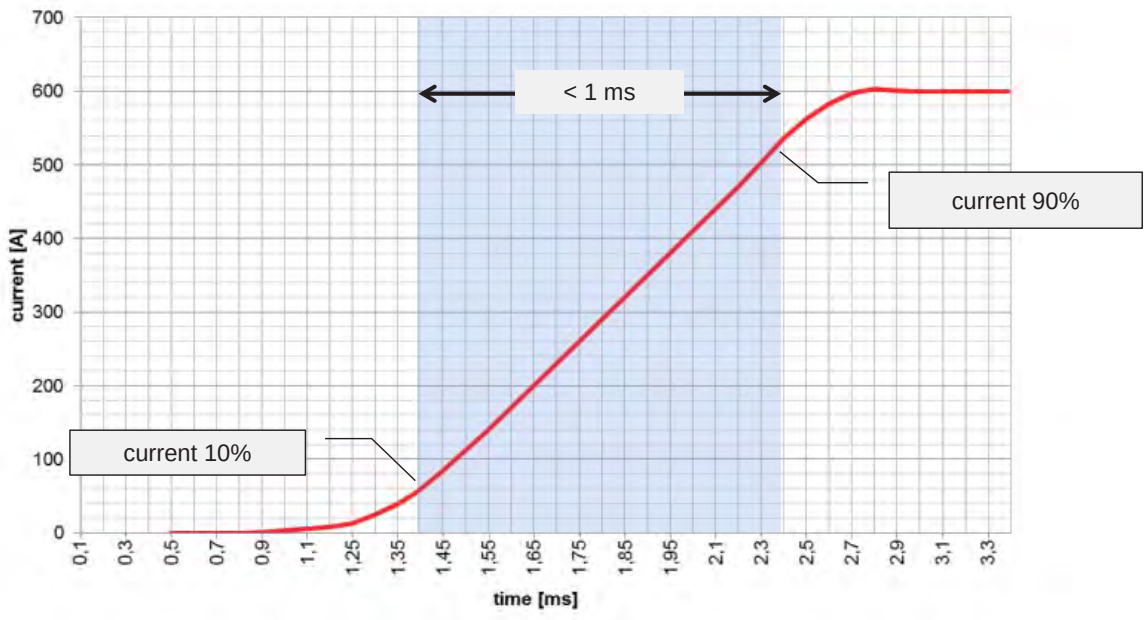
GUSTAV KLEIN
POWER SUPPLIES - since 1948

Mode „Battery Simulator“



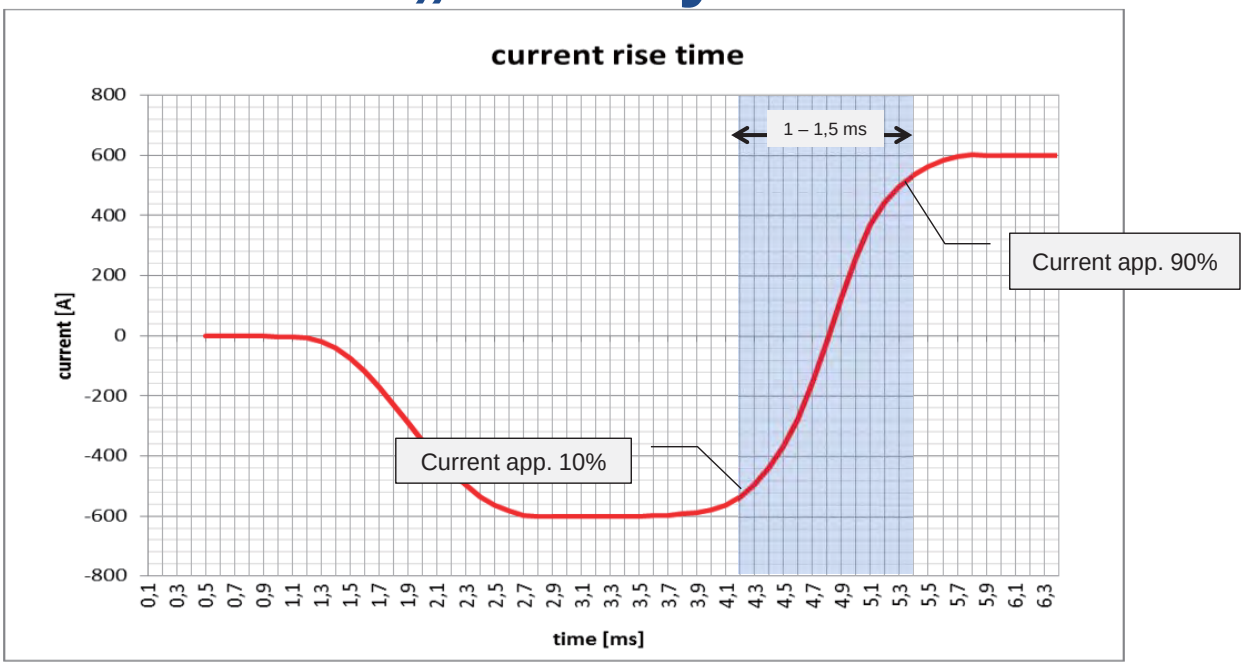
GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Current rise time mode „Battery Tester“



GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Current rise time mode „Battery Tester“



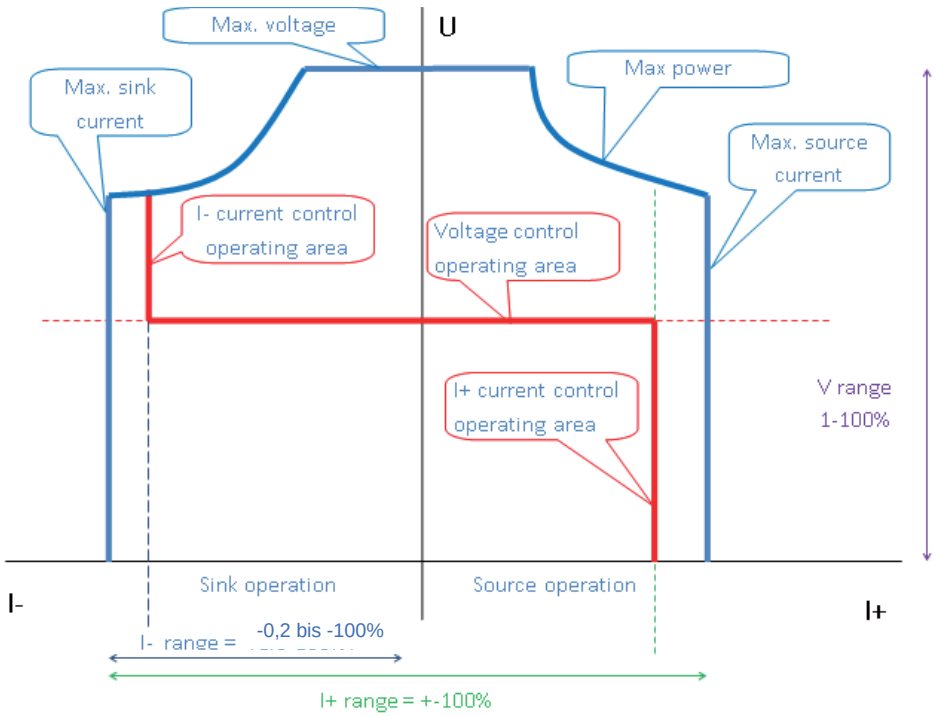
GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Control Modes of I-TS 3870

- 3 independent "control modes"
  - Voltage control (U)
  - Current control (I +)
  - Current control (I -)

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Working of DC Source / Sink



GUSTAV KLEIN POWER SUPPLIES - since 1948

Description Voltage Control "U"

- Constant output voltage at
  - System open circuit
  - Current flow between the two current limits ("I +" and "I")
- Setting operation mode “DC-source”
  - 0 to 100% of the rated voltage
- Setting operation mode “DC-sink”
  - 3V to rated voltage for systems with nominal voltages < 100V
  - 4V to rated voltage for systems with nominal voltages < 400V
  - 5V to rated voltage for systems with nominal voltages > 400V

GUSTAV KLEIN POWER SUPPLIES - since 1948

Description current control "I+"

- Limits the current flow to the rated current
  - by lowering the output voltage
- Setting of "+ 100% to" -100% "
- Direct transition from the operation mode DC-source to DC-sink (charge or discharge)
- Transition from the source to sink operation is "seamless" within normal response time

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Description current control "I-"

- Limits the negative current flow
  - by increasing the output voltage
- Setting of “-0,2% to -100%”
- Priority of the “current controller I-” is higher than the “current controller I+”
- Protection of the load (battery) from deep discharge
- Active if voltage level of the connected load is higher as voltage level setting of controller.
- For battery discharging not required (but can be used)

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Description "power limitation“

- If the operating point of the device is greater than the maximum power of the device
  - Dynamic adjustment of the current level when "I +" or "I" control active
  - Dynamic adjustment of the voltage level when "U" - Control active

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Protection features
(included in the basic system)

- Overvoltage protection (OVP)
  - At the output
  - At the mains input
- Under Voltage Protection (UVP)
  - At the mains input
- Over temperature protection (OTP)
  - At all power units
- Current limiting (OCP)
  - Static "I +" control
  - Static "I -" control
  - Dynamic using „transistor current limit"

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Safety concept
EN ISO 13849 / EN60204

EN ISO 13849

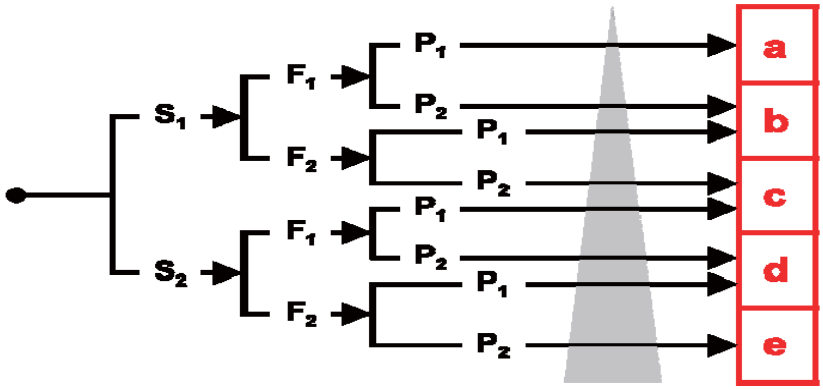
- Title
  - Safety of machinery
  - Safety related parts of control system
  - Part 1: general principles for design
  - Part 2: Validation
- Demand of Performance Level
  - Achieved Performance level „d“

EN 60204 - 1

- Title
  - Safety of machinery
  - Electrical equipment of machinery
- Demand
  - Definition the color of wires
  - Identification mark of component
  - Relay with auxiliary contact incl. monitoring
  - Main switch
  - Safety components for emergency stop
  - Sensor- and actor loop are redundant
  - Confirmation of functional safety

GUSTAV KLEIN
POWER SUPPLIES - since 1948

Risc flow route acc. EN ISO 13849-1 to achieve different performance level



- S1: slightly, reversible injury
- S2: severe injury, death
- F1: rarely till less frequently and / or short takes exposition
- F2: frequently till constant and / or long exposition
- P1: avoidance of danger under certain conditions possible
- P2: avoidance of danger rarely possible

GUSTAV KLEIN
POWER SUPPLIES - since 1948

Safety control unit for performance level „d“

(included in the basic system)

All input and output signals are through two channels.

Insulation – monitoring
(included in the basic system)

- Insulation monitoring in the DC output circuit
  - When falling below R_{iso} <100k the system will be stopped
  - The Insulation monitor will be switched over or off in parallel operation of two systems with relays on A70.
    (2 Insulation monitors cannot be active)
  - For fixed parallel operation the Insulation monitor the 2nd unit is not necessary (Insulation monitor can be switched off)

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Power supply

- Standard System:
- 380-480V (± 10%) 3/(N)/PE, 50/60Hz (± 6%)
- Input voltage range of 500V and 690V with additional price depending on the power of the system
- Input voltage range of 208V and 220V with additional price depending on the power of the system

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

Efficiency

- Standard System 800V / 600A
  - Typ. 92–95% (depending on the system power)

Caution:

- Low output voltage reduces the efficiency

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

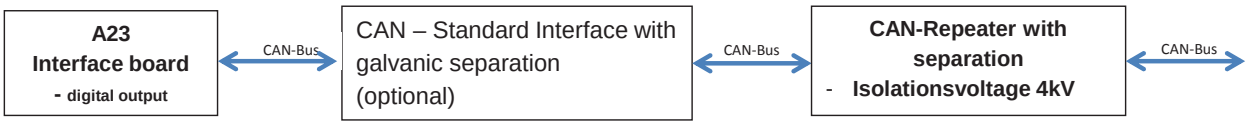
I-TS 3870 display and operation elements

Remark: „emergency off“ button is optional

GUSTAV KLEIN
POWER SUPPLIES - since 1948

CAN-Bus interface

(Standard is not galvanic isolated)



- I-TS 3870 has two CAN bus – Interfaces (named A23)
  - Control of the system using two different control systems are possible (eg tester control and Simulator - control)
  - Switching the CAN bus connection via relay on the "A23"
- By default, only one interface active
- Transmission speed CAN bus = 100Hz (1Mbit)

Caution:

- Max. Distance = 30m
  (for longer distance the "baud rate" has to be reduced)

GUSTAV KLEIN
POWER SUPPLIES - since 1948

Output contactors for "Disconnect under load"

(I-TS-3870-DC-xxx)

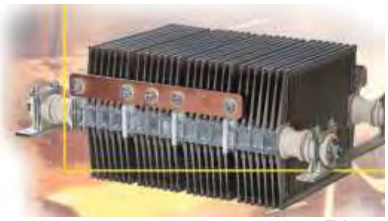
- Output contactors with positively driven auxiliary contacts
- Output contactors for operation "disconnect under load"
  - Max. 1000 A / 1000 V

GUSTAV KLEIN
POWER SUPPLIES - since 1948

Discharge Unit for operating mode „simulator“

(I-TS-3870-DCU-xxx)

- Operates according to the closed circuit principle
- Sinks the "residual energy" of the DUT after System-Stop
- Installation in the PDSB possible
- Only for "simulator" usable
  - Activation after "stop" or "emergency stop" or overvoltage (eg >850 V with Standard - System)
  - Resistor is connected to the DC output (after the output contactor) -> always active
  - Customer has to ensure that max. Energy is not exceeded (1sec @ nominal power)

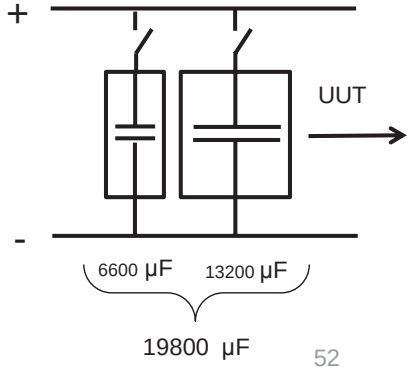


GUSTAV KLEIN
POWER SUPPLIES - since 1948

Increase output capacitor for operating mode "simulator"

(I-TS-3870-O-CAP-xxx)

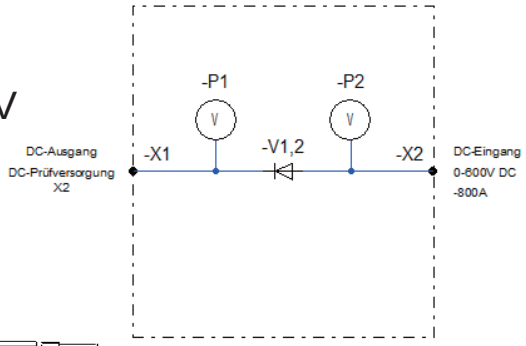
- 3 different capacitors can be selected at the control panel.
  - 6600µF, 13200µF and 19800µF
  - Automatic integration into the control loop for optimal performance
- Advantage:
  - Reduction of downtime due to voltage dips at special DUT (installation of an additional capacitor-box)
  - Customer specific test conditions for optimal performance

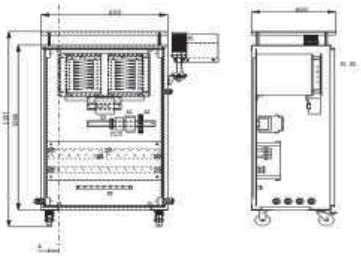


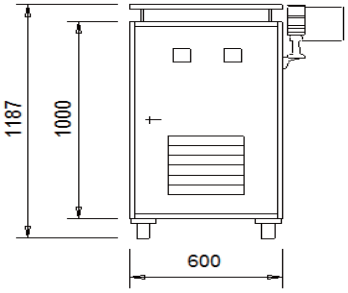
Protection diode for "safe“ sink operation

(I-TS-3870-Diode-800A)

- Cabinet with wheels
- Protection diode for 1200 A and 800 V
- Signal lamp as status display
- Voltage display







Protection class IP21

(I-TS-3870-IP21)

GUSTAV KLEIN
POWER SUPPLIES - since 1948

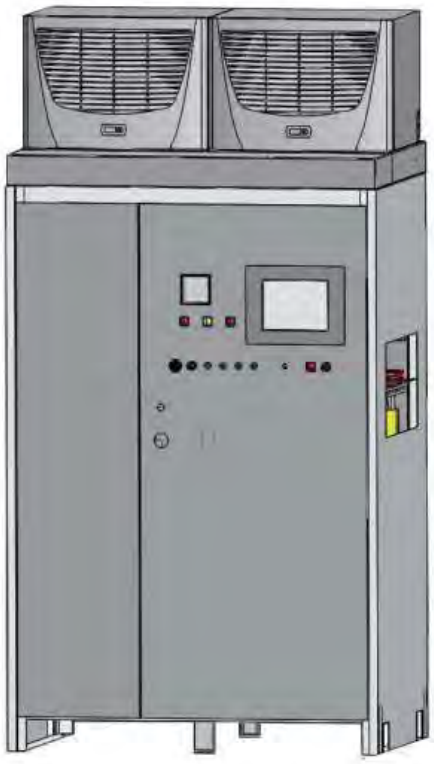
Protection class IP23

(I-TS-3870-IP23)

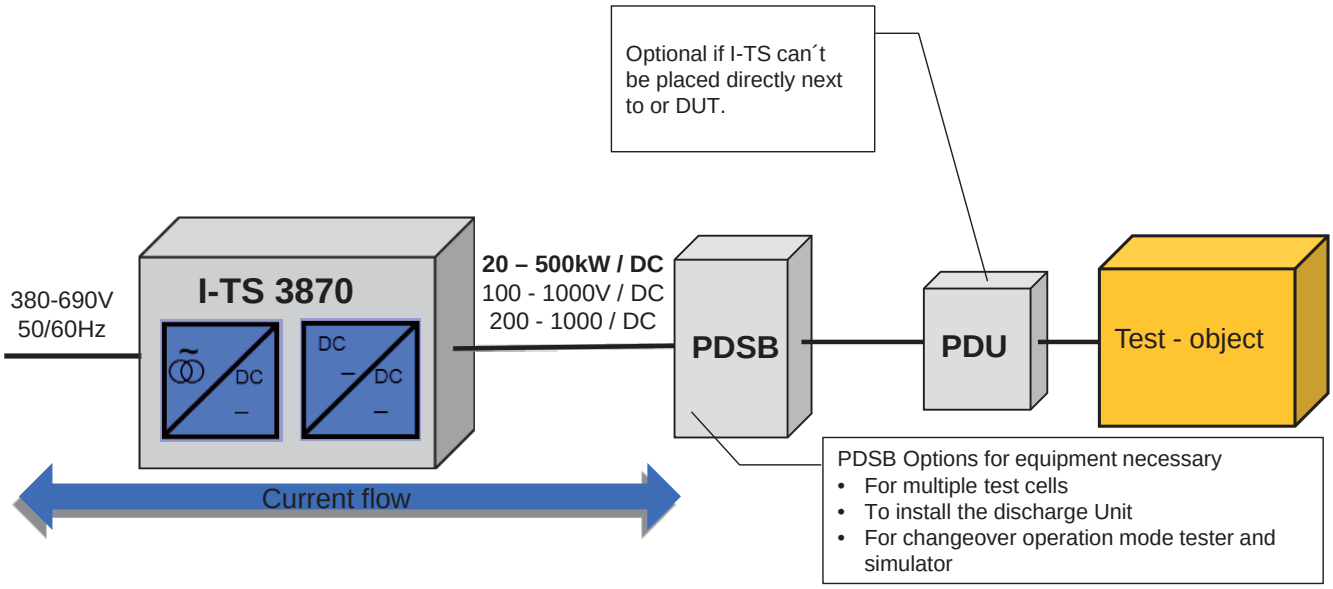
GUSTAV KLEIN
POWER SUPPLIES - since 1948

Protection class IP53

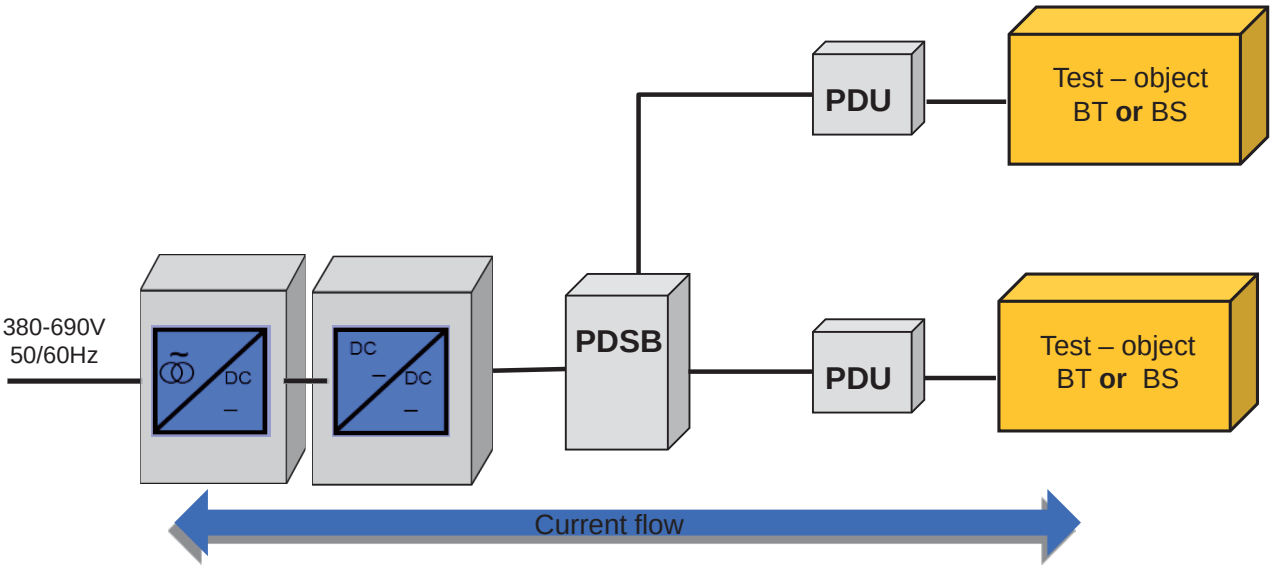
(I-TS-3870-IP23)



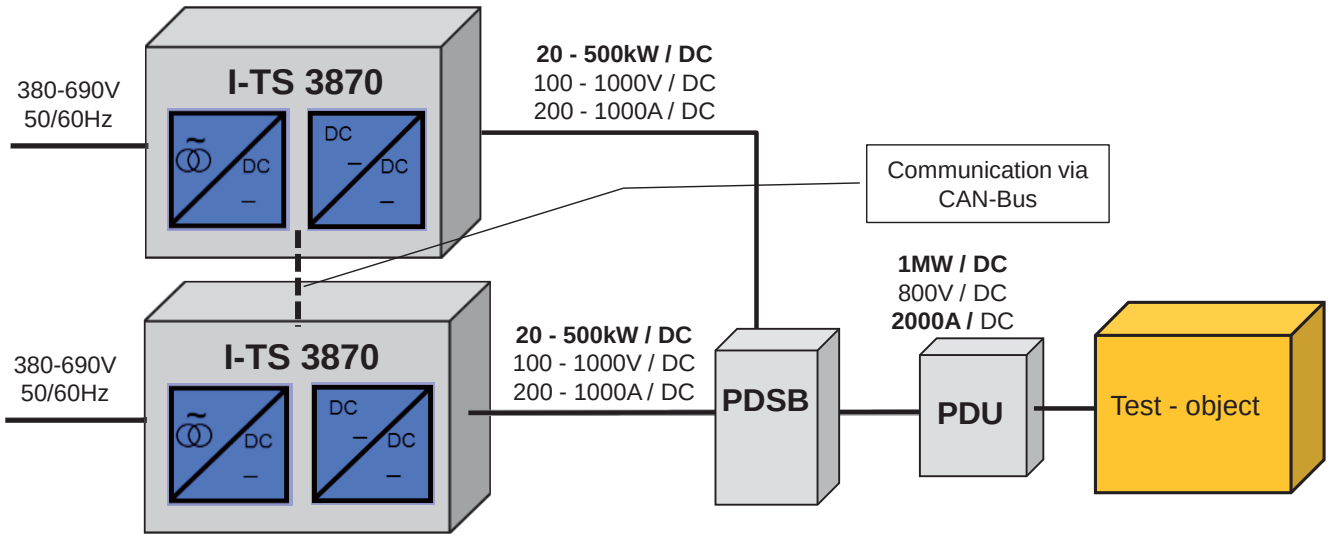
I-TS 3870 single – standard system



I-TS 3870
Changeover test cells / DUT



I-TS 3870 parallel – system
(I-TS-3870-parallel)



PDSB
(Power distribution switch box)
(I-TS-3870-PDSB-xxx)

- Cabinet to connect various contactors and Discharge Unit
- Standard types
  - 1 input / 2 outputs (for two test rigs)
  - 2 inputs / 1 output (power increase of parallelization)
- Protection class IP20
- Dimensions depending on the version

GUSTAV KLEIN
POWER SUPPLIES - since 1948

PDSB
(Power distribution switch box)

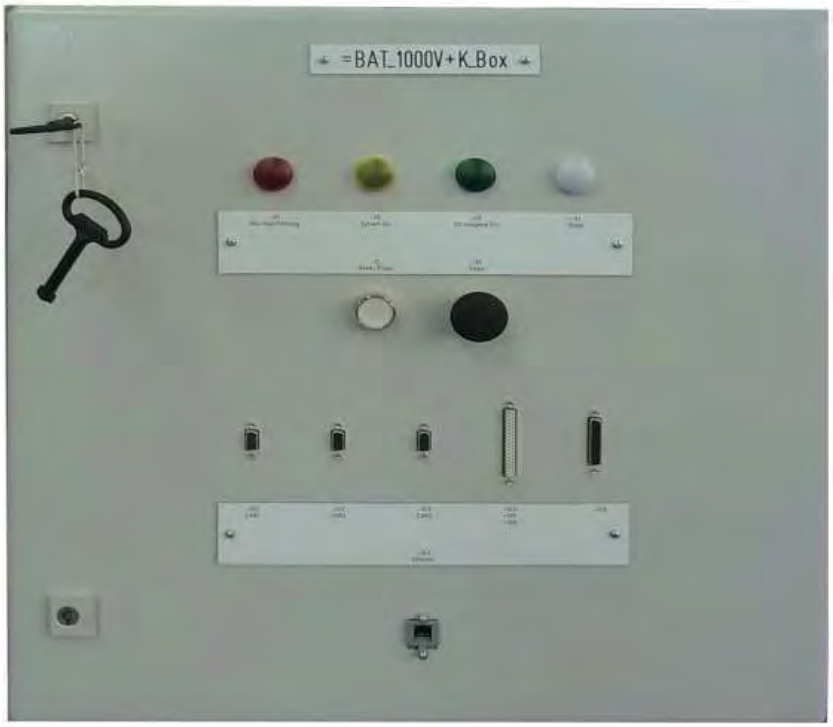
GUSTAV KLEIN
POWER SUPPLIES - since 1948

PDU (Power distribution unit)
(I-TS-3870-PDU-xxx)

- Wall cabinet for connecting the device under test (1000V / 600A)
- Wall housing for a test - cell (BT or BS)
  - 800mm x 300mm b t x 1000mm h
  - Protection class IP 54
  - Voltmeter Cabinet Door
  - Short-circuit switch (Q4) for secure connection of test objects -> Before working on the unit, the switch Q4 is too close (only Simulator - PDU)
  - Traffic light indicates operating status
  - Indicator light for status of isolation monitor (turned off or active)

GUSTAV KLEIN
POWER SUPPLIES - since 1948

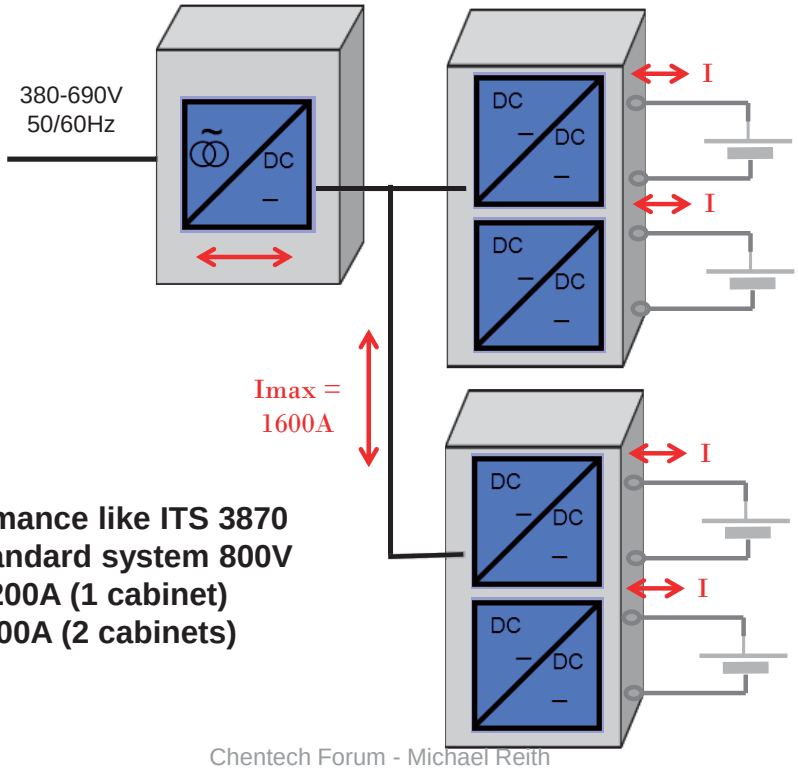
PDU (Power distribution unit)



GUSTAV KLEIN
POWER SUPPLIES - since 1948

Multi channel Infeed - Test System

MI-TS 3871



Power performance like ITS 3870
Outputs of standard system 800V
Max. 4 x 200A (1 cabinet)
Max. 4 x 600A (2 cabinets)

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

View to Future
I-TS V3.0

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

New Mechanical Features

- Fire-retardant cabinet
  - (according UL 94-5VB and UL 94-V1 for fixtures)
- Reduced noise emissions
- No distance to wall required for cooling
- Depth 800mm (up to 320kW)
- Improved cooling concept
- Optimized positioning of components
- Ease of maintenance
  - (changing fans and capacitors)

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

New Electrical Features

- Optimized measuring transducer
  - Sustainability
  - Better signal / noise ratio
- Optimized design of transformer and chokes
  - Less acoustic noise
  - Better dynamic performance
- Reduced reactive input power
  - Advantages when using system with part load

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948

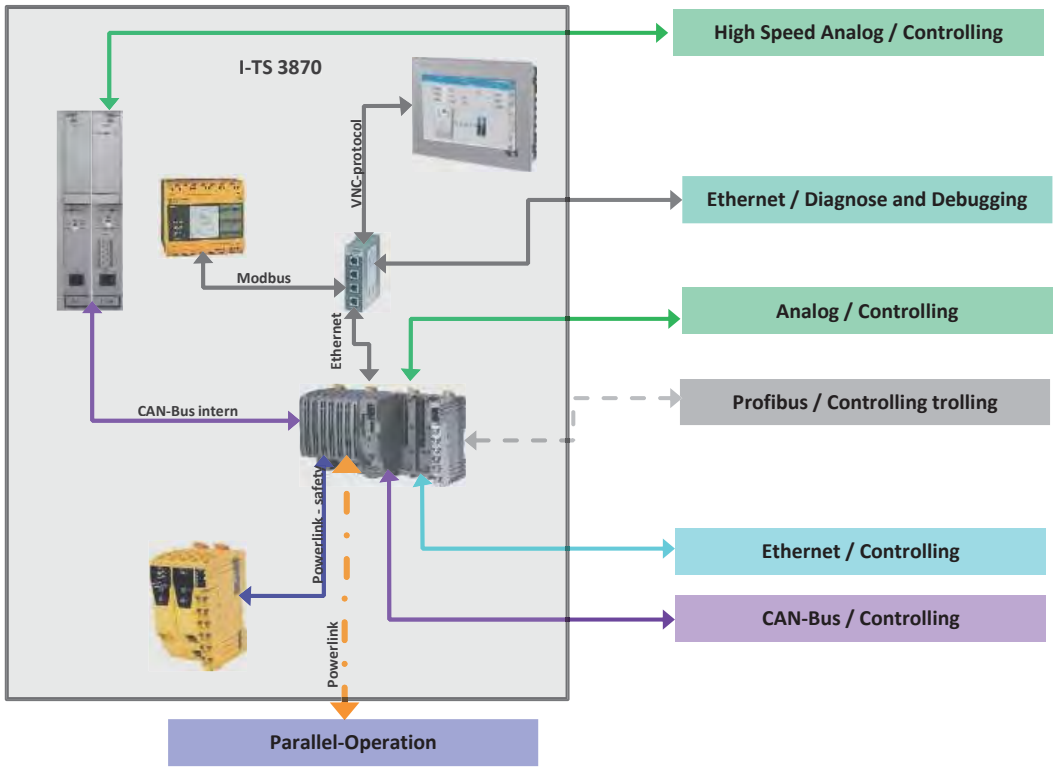
New Controller

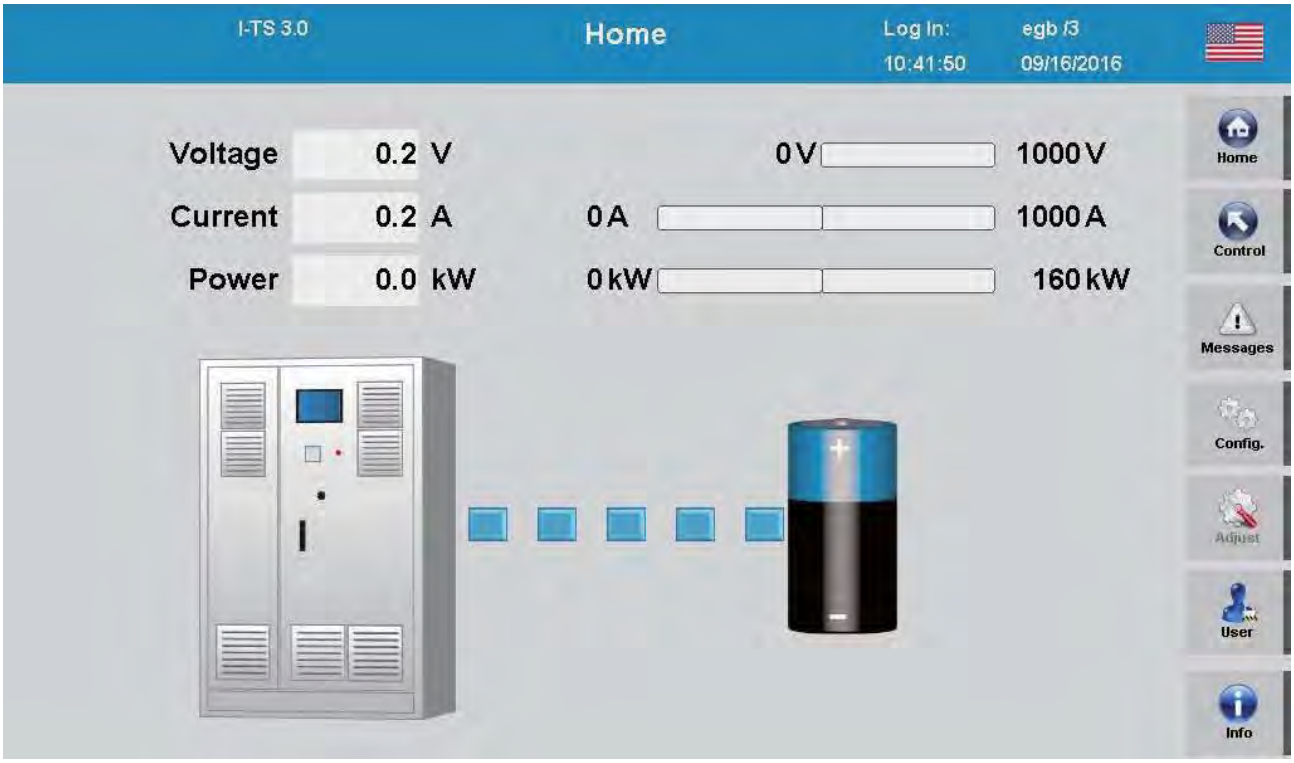
- TFT with touchpanel
- Earth fault monitoring device (optional)
  - (newest technology, handling is integrated in TFT)
- Firmwareupdate by USB-stick
- Event-logger
  - Opportunity to download the logs (CSV file)
- Data-logger (optional)
  - Logging of measuring values of test procedures
- Signal generator for simple test procedures
- Parallel operation for up to 4 systems

New Interfaces

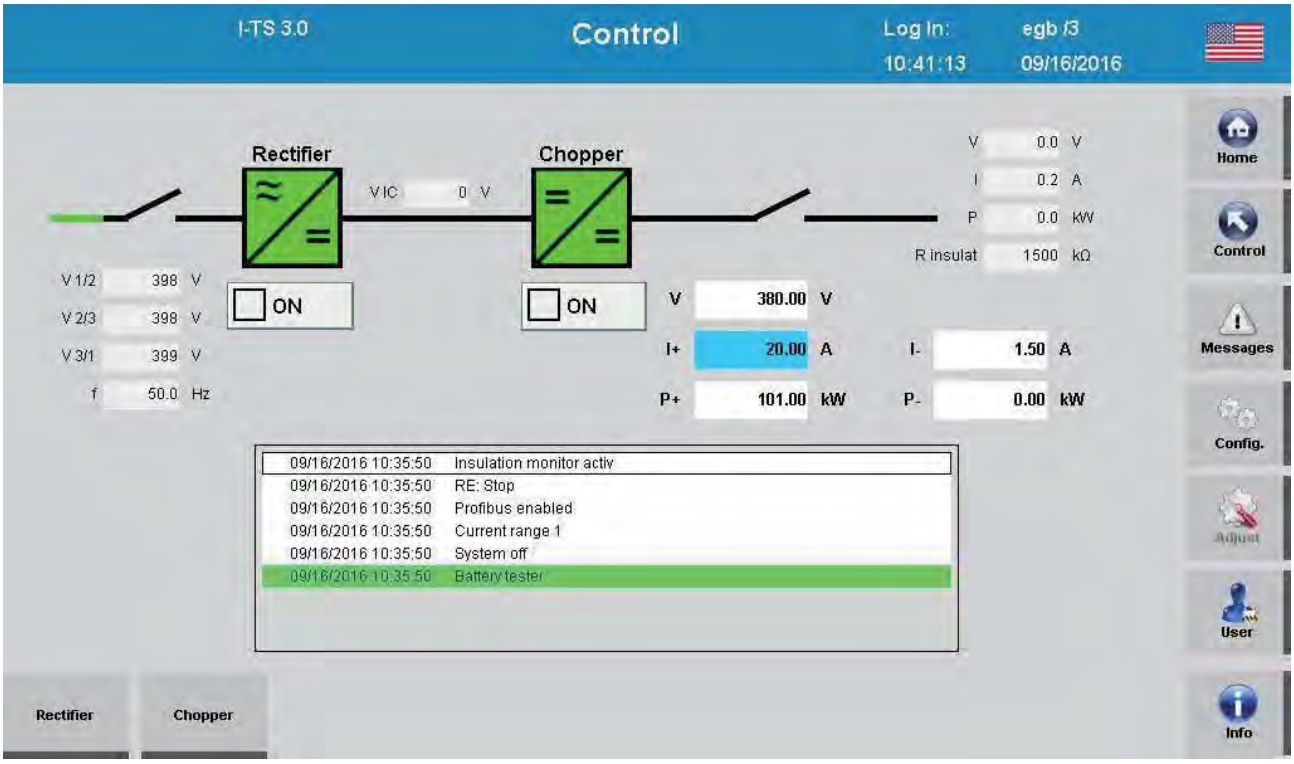
- Standard interfaces:
  - Modbus TCP/IP
  - CAN
- Optional available interfaces:
  - SCPI (TCP/IP)
  - Profibus
  - ProfiNet
  - Analogue 0-10V
  - High-Speed analogue for currnet
- Remote access by Teamviewer
  - (B&R Automation Studio and separate Ethernet are required)

GK GUSTAV KLEIN
POWER SUPPLIES - since 1948





GK GUSTAV KLEIN
POWER SUPPLIES - since 1948



GUSTAV KLEIN
POWER SUPPLIES - since 1948

Come and visit us in Bavaria

High Power EV Battery Test Solution

Part 3: PBT-1000 Series software introduction

Curtis Lin

Outline

- Company Introduction
- Testing Technologies of PBT-1000
- Conclusion
- Demonstration

ABOUT CTE

Battery Research

Material Research

Battery Capacity & Life Cycle Research

SOH Research

Battery Production

Formation

Grading

Learning

Quality Check

WORLDWIDE BATTERY TESTING EXPERT

30+ years experiences

300+ worldwide customers

300,000+ channel sales records

CHEN TECH ELECTRIC

Worldwide Locations

承德科技 CHEN TECH ELECTRIC

CHEN TECH ELECTRIC

TESTING TECHNOLOGIES OF PBT-1000

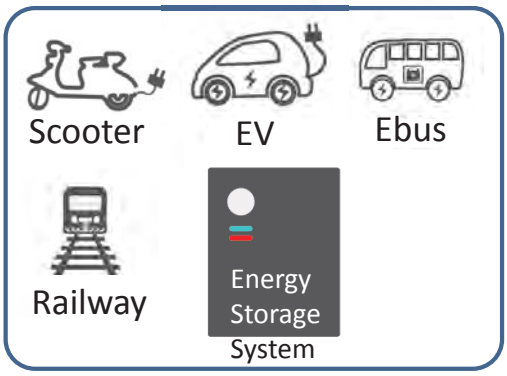
承德科技 CHEN TECH ELECTRIC

CHEN TECH ELECTRIC

Germany Technology

PBT 1000 Series

Eco-High Power Pack Evaluation & Testing System



HIGH Power

High Power
Up to 500KW

充放 快速轉換

<2ms
charge/discharge switch time

工況模擬

FUDS, DST
and customized testing patterns

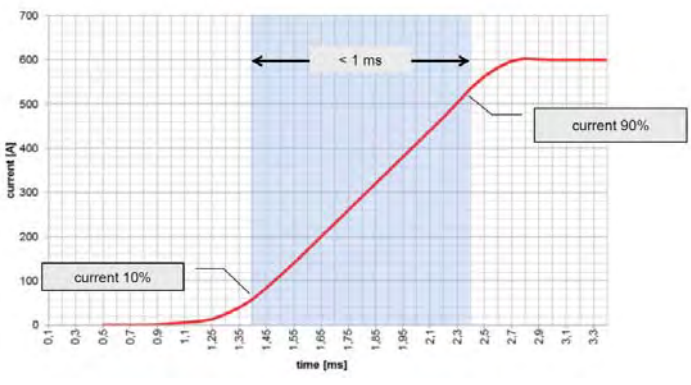
放電能量

95%
discharge recycle efficiency

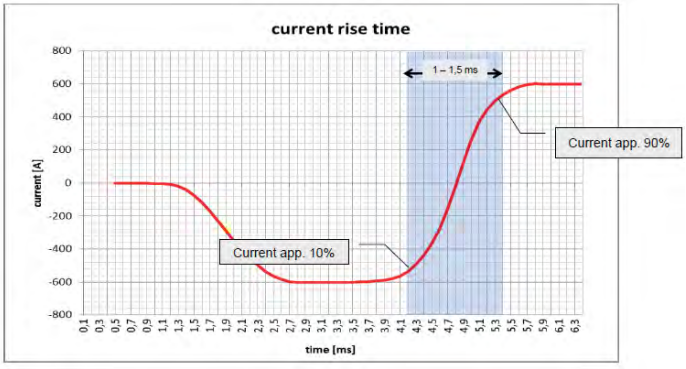
承德科技 CHEN TECH ELECTRIC

CHEN TECH ELECTRIC

Current Response & Mode Switch



Rapid Current Response during Charge and Discharge



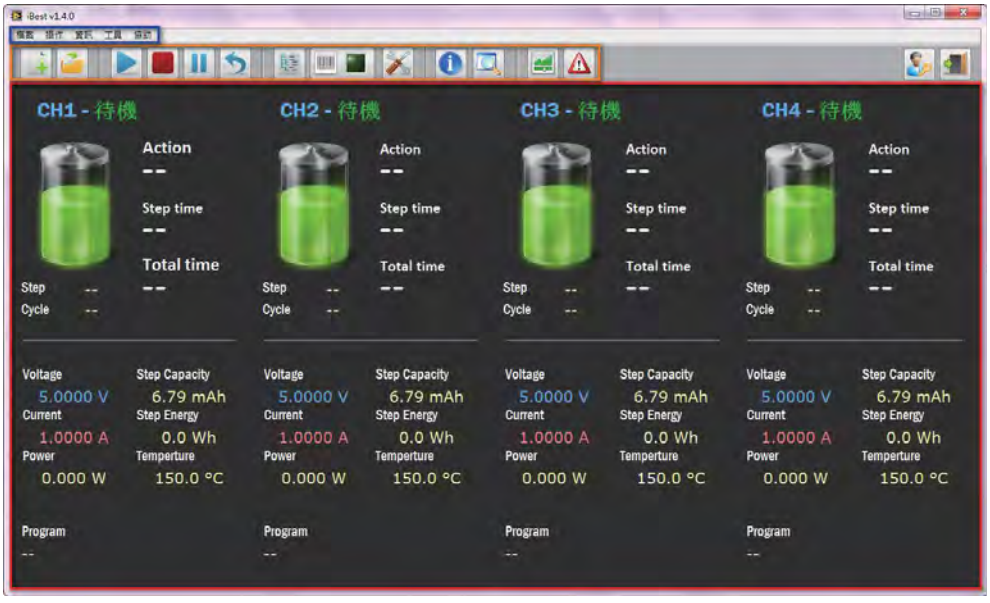
Rapid Switch Between Charge and Discharge

承德科技 CHEN TECH ELECTRIC

The Features of Software - iBest

- BMS communication and data collection
- Cell voltage and temperature measurement
- Chamber control integration
- Battery testing standard integration
- Powerful data analysis function
- Abnormal charging or discharging diagnosis

iBest



BMS communication and data collection (1/2)

Battery Pack

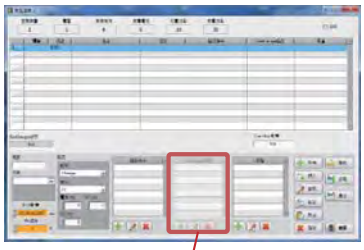
1. Can
2. RS-485
3. Modbus
4. Uart
5. SMBus

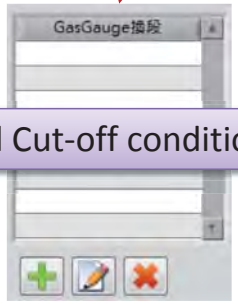
PBT-1000

1. BMS Data Collection
2. BMS Reading/Writing

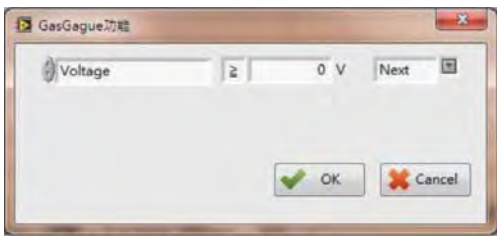
https://www.google.com.tw/search?hl=zh-TW&bih=770&biw=1440&tbm=isch&sa=1&q=EV+PACK&oq=EV+PACK&gs_l=img.3..0i8i30k1l2.70038.75267.0.75610.7.7.0.0.0.0.130.423.6j1.7.0....0...1c.1j4.64.img..0.7.421...0j0i30k1j0i19k1.jRotGpaqGPs#imgrc=YegHi0hS2ob1tM%3A

BMS communication and data collection (2/2)





Add Cut-off conditions



	Battery 1 (RS-485)	Battery 2 (CAN)
1	Voltage	Voltage
2	Current	Current
3	Full Capacity	State Of Charge
4	State Of Charge	Cycle Count
5	Cycle Count	Flags-Warning
6	Flags-Normal Alarm	Flags-Error 1
7	Flags-High Alarm	Flags-Error 2
8	Flags-Status	Flags-Permanent Error

CHEN TECH ELECTRIC

Voltage and Temperature collector - ES-100B/ET-100B

Auxiliary Voltage/ Auxiliary Temperature

Auxiliary voltage and auxiliary temperature are for collecting the voltage and temperature data of single cell in the battery pack. Every module contains 24 measurement points. The data recording time is 100ms and the accuracy is at 0.02% F.S. Collected data can be used as step cutoff conditions while running battery test, improving the flexibility of production line and laboratory.

ES-100B Auxiliary Voltage	
Channels	24
Measurement Range	±64V, ±32V, ±8V
Measurement Resolution	16 bit
Measurement Accuracy	0.02% F.S.
Data Recording Time	100ms (24ch)

ET-100B Auxiliary Temperature	
Channels	24
Measurement Range	-50~150°C*
Measurement Resolution	0.1 °C
Measurement Accuracy	±1°C (-40~90°C)
Data Recording Time	100ms (24ch)

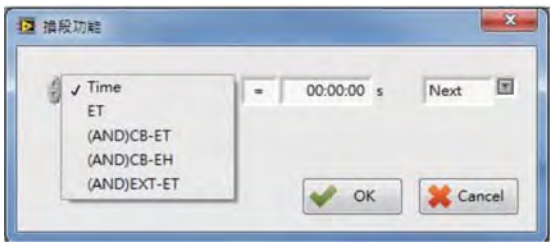
*Depend on chosen thermal sensors

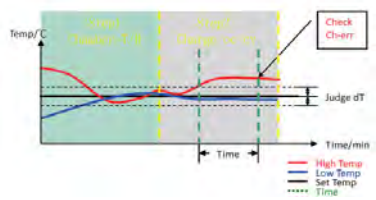
承德科技 CHEN TECH ELECTRIC

CHEN TECH ELECTRIC

Chamber Control Integration

Action	Add mAH	Add WH	Ch-T	Ch-H
CB-T/H Set	0.00	0.00	50.00	0.00
CB-T/H Set	0.03	0.00	50.00	0.00
CB-T/H Set	0.05	0.00	50.00	0.00
CB-T/H Set	0.09	0.00	50.00	0.00
CB-T/H Set	0.11	0.00	50.00	0.00
CB-T/H Set	0.14	0.00	50.00	0.00





承德科技 CHEN TECH ELECTRIC

CHEN TECH ELECTRIC

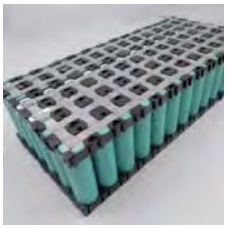
Battery testing standard integration

Cell

https://www.easyacc.com/media-center/best-18650-battery/

- IEC 62660-1 (CNS 15391-1)
- IEC 62660-2 (CNS 15391-2)
- IEC 62660-3
- SAE J2464
- UN38.3
- QC/T 743
- …

Module



http://wholesaler.alibaba.com/product-detail/XTY602020-3-7v-180mah-Small-Lithium_60253803196.html

- UL 2580
- UN38.3
- SAE J2464
- QC/T 743
- GB／Z 18333.1
- …

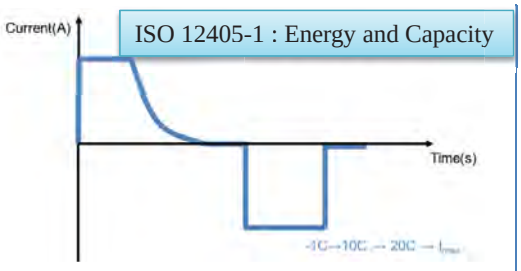
Pack

https://www.google.com.tw/search?hl=zh-TW&bih=770&biw=1440&tbm=isch&sa=1&q=EV+PACK&oq=EV+PACK&gs_l=img.3..0i8i30k1l2.70038.75267.0.75610.7.7.0.0.0.0.130.423.6j1.7.0....0...1c.1j4.64.img..0.7.421...0j0i30k1j0i19k1.jRotGpaqGPs#imgrc=YegHi0hS2ob1tM%3A

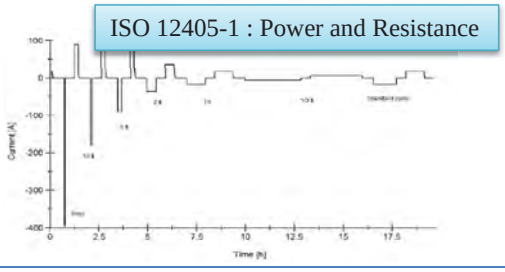
- ISO 12045-1 (CNS 15369-1)
- ISO 12045-2 (CNS 15369-2)
- ISO 12045-3 (CNS 15369-3)
- UNECE R100
- GB 24155
- GB 24158
- UN38.3
- EN15194
- SAE J2929
- SAE J2464
- GB／Z 18333.1
- BATSO–01
- UL 2271
- UL 2580
- …

承德科技 CHEN TECH ELECTRIC

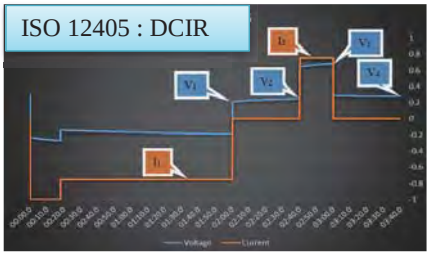
ISO 12405-1 : Energy and Capacity



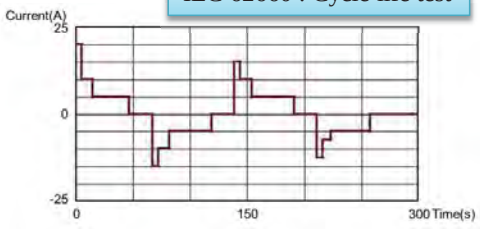
ISO 12405-1 : Power and Resistance



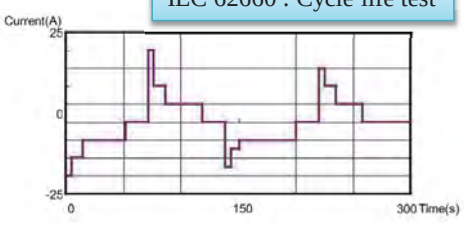
ISO 12405 : DCIR



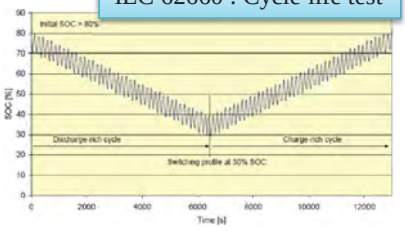
IEC 62660 : Cycle life test



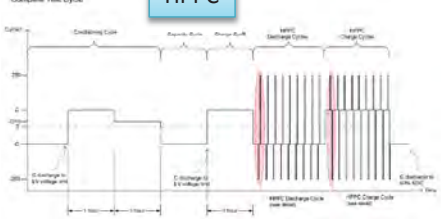
IEC 62660 : Cycle life test



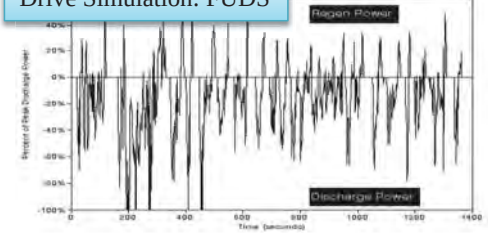
IEC 62660 : Cycle life test



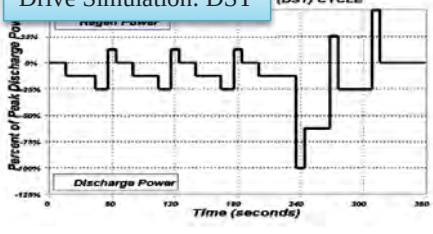
HPPC



Drive Simulation: FUDS



Drive Simulation: DST

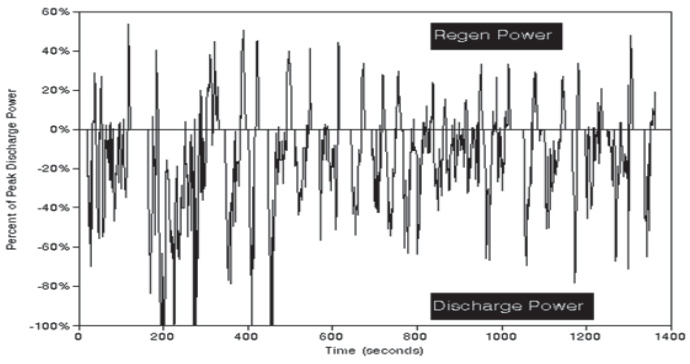


Summarize

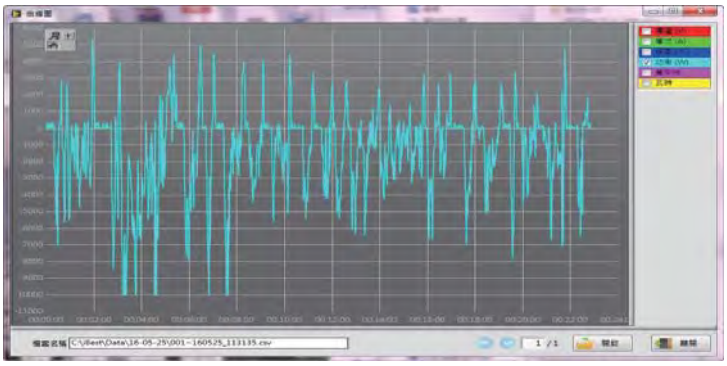
- Capacity
- SOC adjustment
- Power
- Energy
- Storage test
- Cycle life test
- Energy efficiency test
- DCIR
- HPPC
- Drive Simulation
  - FUDS
  - DST

Drive Simulation-FUDS

- FUDS: 20KW 100A

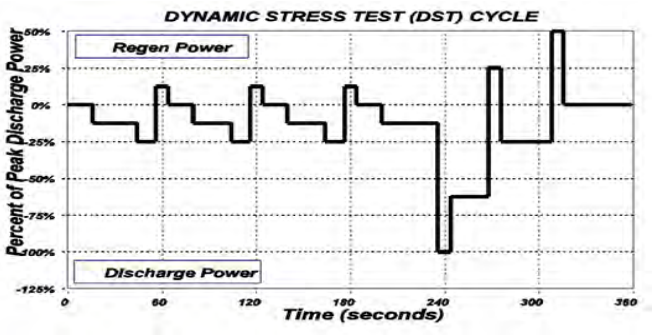


Data Recording using PBT-1000

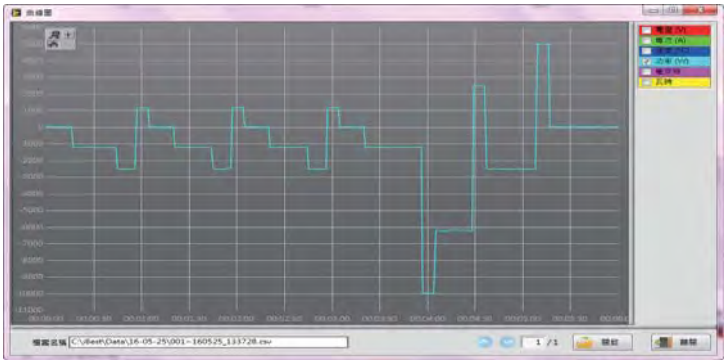


Drive Simulation-DST

- DST 20KW 100A



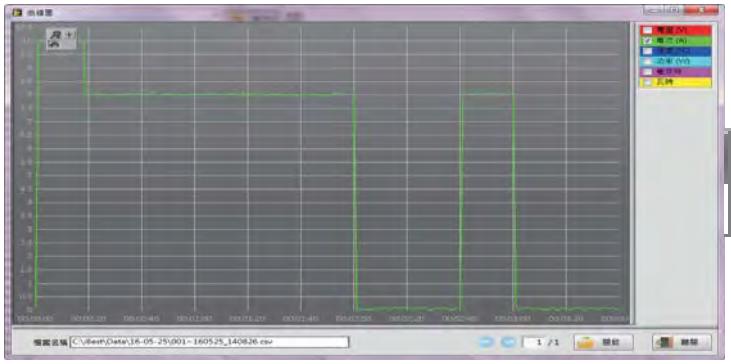
Data Recorded using PBT-1000



DCIR – IEC 61960

- IEC 61960-2003 with 10A Current

Current Recorded in iBest



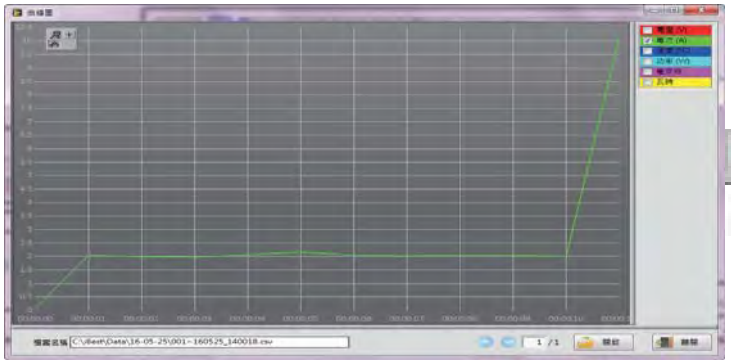
Measured DCIR in iBest

DCIR-C (Ohm)	DCIR-D (Ohm)
1.883240	5.444981

DCIR – ISO 12405

- ISO 12405 with 10A Current

Current Recorded in iBest



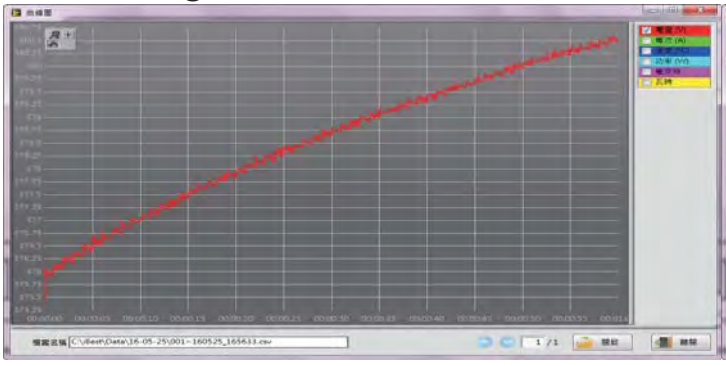
Measured DCIR in iBest

DCIR-C (Ohm)	DCIR-D (Ohm)
	0.905097

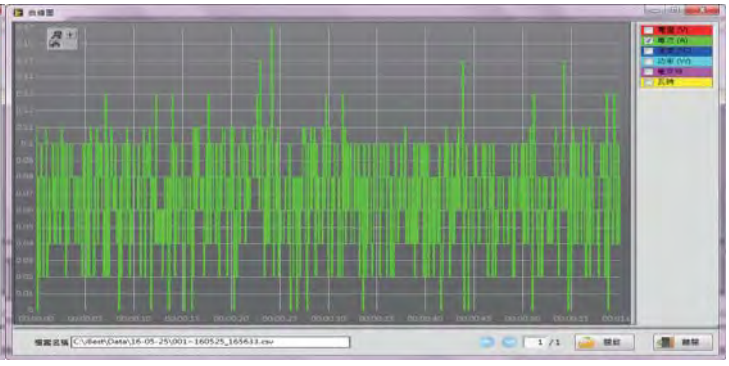
Waveform (PWM Pulse)

- No Step Limitation
- Example: Current 0A~100A, Duration: 10ms~500ms

Voltage Recorded in iBest



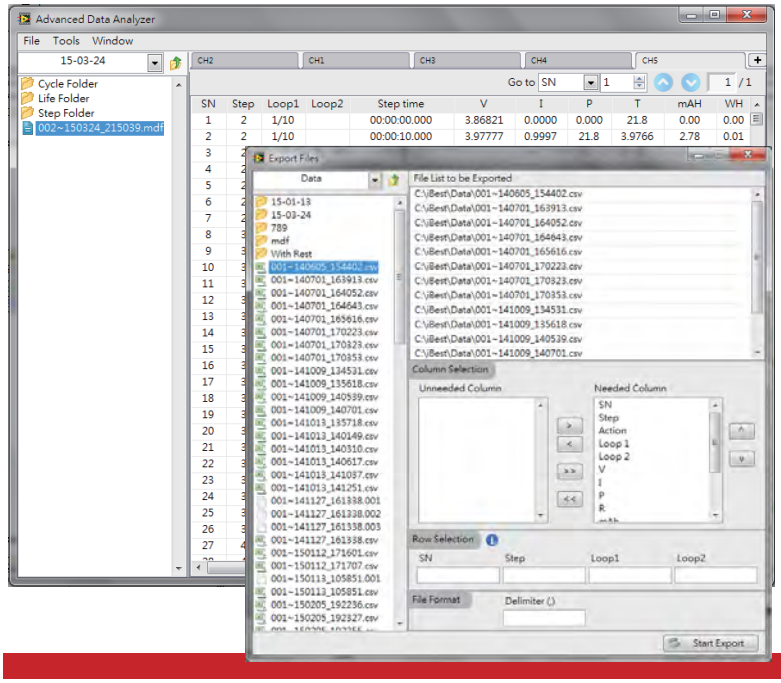
Current Recorded in iBest

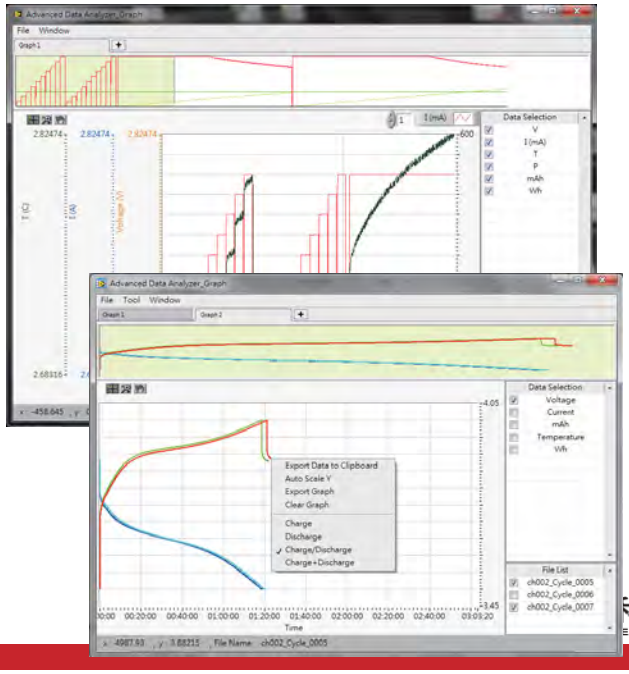


Data analyzer (1/3)

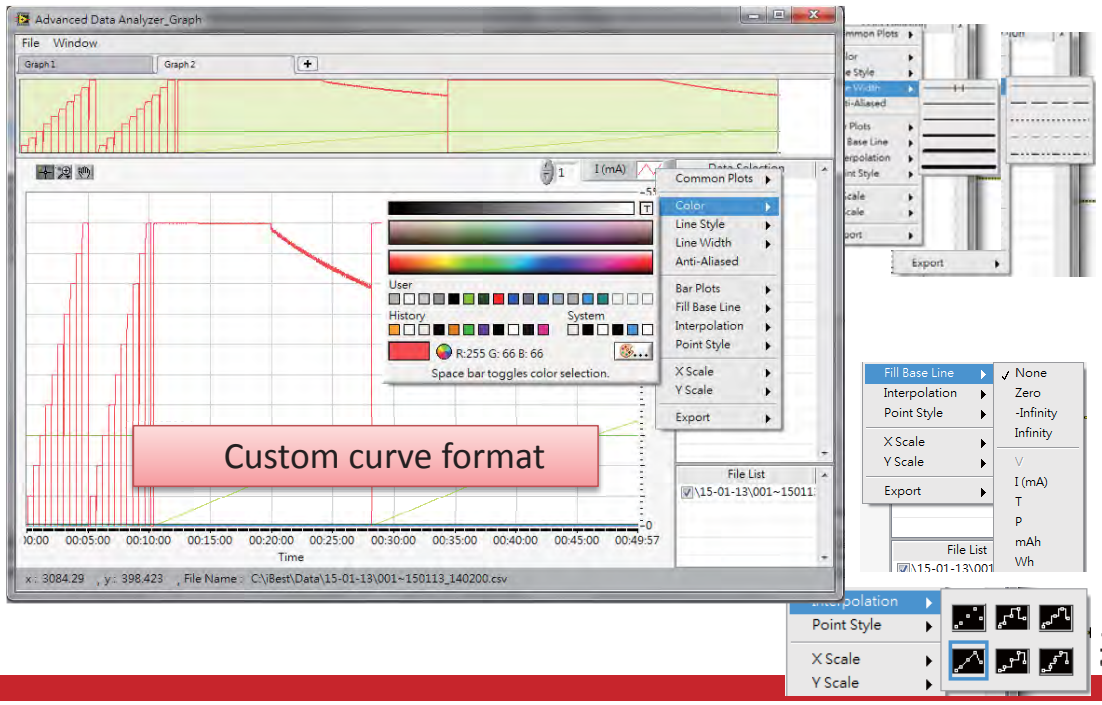
- Table View
  - Custom field exportation
  - Copy&Paste
- Curve View
  - Axis type selection
  - Multi-y axis
  - Overlay analysis
  - Custom curve format
  - Copy&Paste

Data analyzer (2/3)





Data analyzer (3/3)



Multilayer Protection Features

	1st Protection	2nd Protection	3rd Protection
OV (OVP)	At the output At the mains input	Highest voltage protection	Oerr (Real time output characteristic diagnosis (dv/dt, dT/dt, …))
LV (UVP)	At the mains input	Lowest voltage protection	Oerr
OC (OCP)	Static “I+” control Static “I-” control Dynamic using “transistor current limit”	Highest current protection	Oerr
LC	NA	Lowest current protection	Oerr
OT (OTP)	At power units	Highest temperature protection	Oerr
Verr	NA	Inaccuracy protection	Oerr
Cerr	NA	In accuracy protection	Oerr

CHEN TECH ELECTRIC

CONCLUSION

承德科技 CHEN TECH ELECTRIC

CHEN TECH ELECTRIC

Conclusion

- PBT-1000 is a ready system for battery testing
  - Solid hardware performance
  - Integrated software utilities
- Trail use program: We welcome you to test your battery in CTE

承德科技 CHEN TECH ELECTRIC

CHEN TECH ELECTRIC

DEMONSTRATION

承德科技
CHEN TECH ELECTRIC

電動車汰役電池
測試相關標準介紹

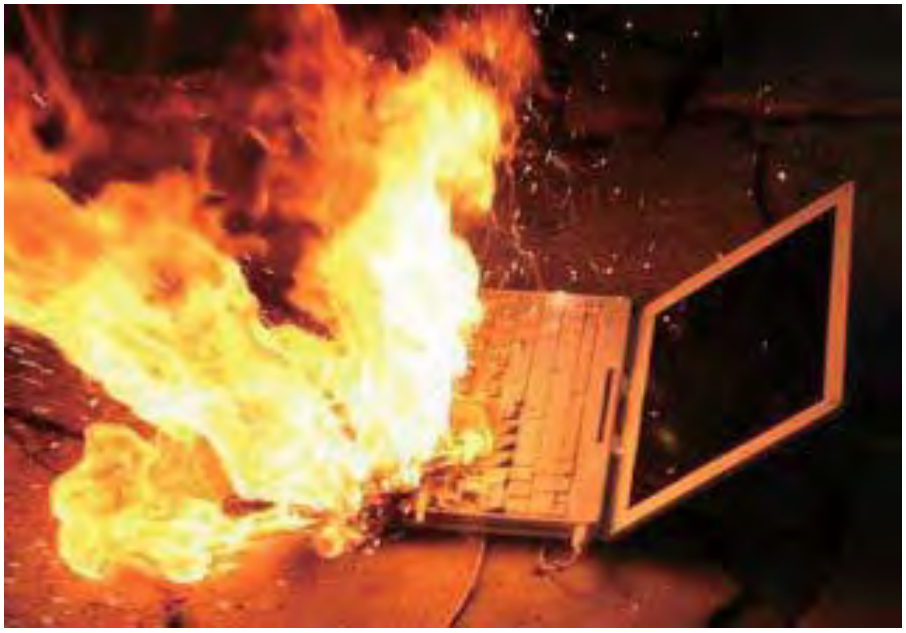
Benjamin.Chen@ul.com
+886-987-587-021
2016/10/14

Agenda

- 汰役電池的安全風險在哪裡？
- 汰役電池該檢測哪些項目？

電池組用久了，會有甚麼問題？

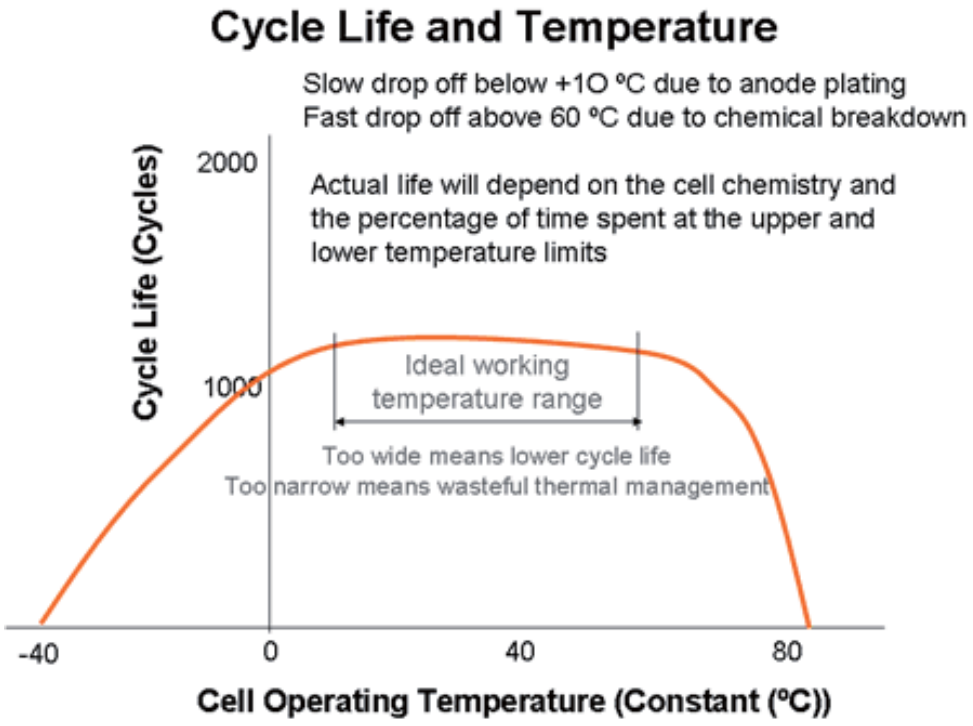
就這麼燒起來了？



Source: http://news.softpedia.com/news/Apple-and-Sony-Pay-1-3-Million-Yen-in-Battery-Fire-Lawsuit-83438.shtml#sgal_0

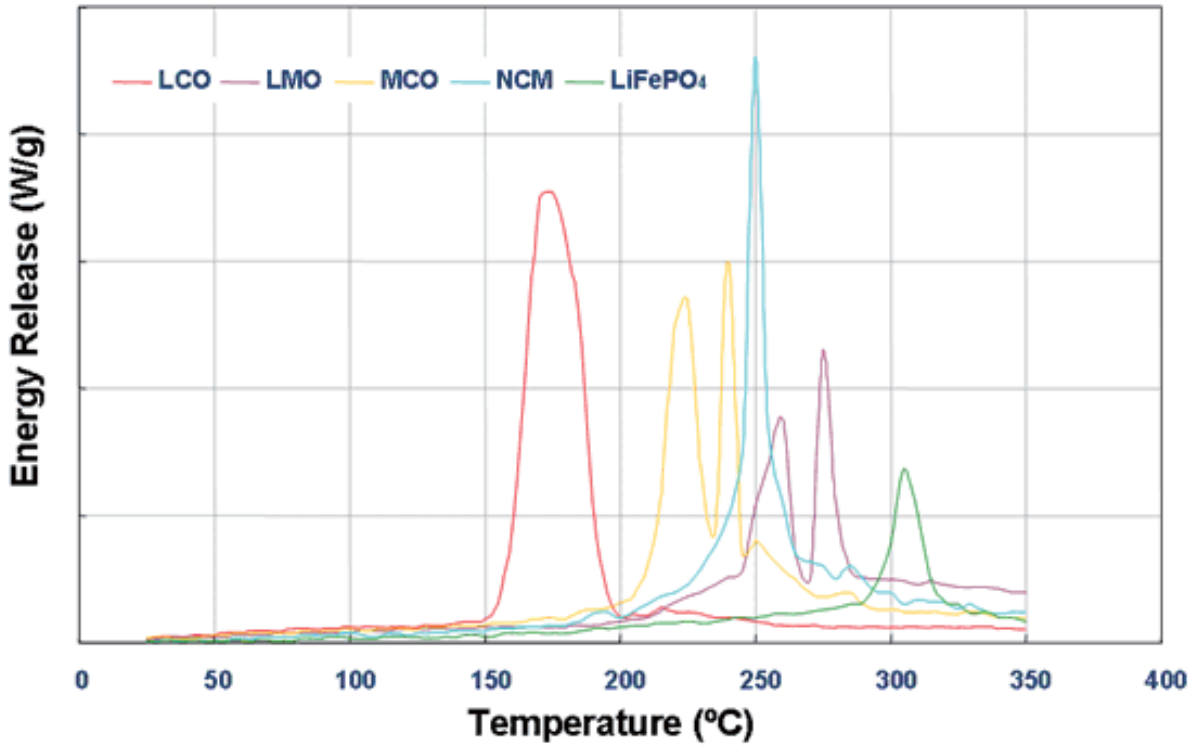
就這麼燒掉了一台飛機？
FEDEX –Memphis incident

工作溫度是個問題？



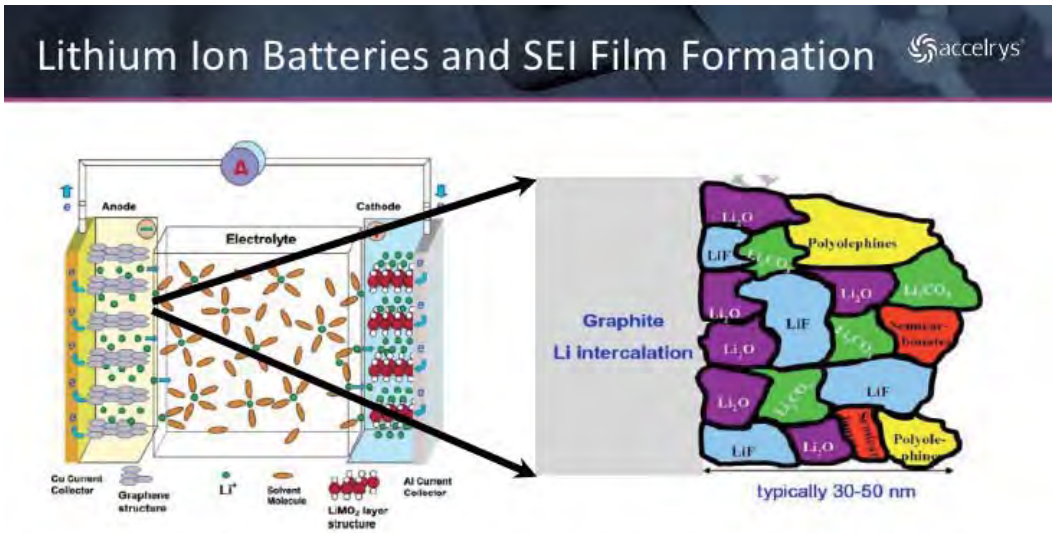
Source: http://www.mpoweruk.com/lithium_failures.htm

太高的工作溫度會有甚麼問題？



Source: http://www.mpoweruk.com/lithium_failures.htm

鋰電池的壽命關鍵
SEI – Solid Electrolyte Interface



- The electrolyte typically consists of one or more lithium salts dissolved in an aprotic solvent with at least one additional functional additive
- Additives are included in electrolyte formulations to increase the dielectric strength and enhance electrode stability by *facilitating* the formation of the solid/electrolyte interface (SEI) layer

過充過放的電池有什麼問題？

Abstract No. 110

Swelling Mechanism of the Lithium Ion Batteries at High Temperature

Kyoung-Hee Lee, Euihwan Song, and Hong S. Lim
Corporate R&D Center, Energy Development Team
Samsung SDI Co., Ltd
428-5, Gongse-Ri, Kiheung-Eup, Yongin-City,
Kyonggi-Do, Korea

Below the 80% of SOC, the thickness changes of the Li-ion batteries are almost constant as a function of SOC and the values is about 10%. The thickness of the Li-ion batteries, however, abruptly increases above 80% of SOC.

The swelling behavior of the Li-ion batteries must be considered in terms of the distinctive two regions : one is the region below 80% of SOC, and the other is above 80% of SOC. In case of the region above 80% of SOC, the swelling behavior of the Li-ion batteries is expected to be attributed to the side of cathode. In case of the region below 80% of SOC, the reason for the swelling of the Li-ion batteries is concerned with the side of anode.

The cell containing the cathode swells above the certain voltage, namely, 4.0V versus Li/Li^+, indicating that the swelling behavior of the cell containing the cathode is attributed to the oxidation of electrolytes on the cathode.

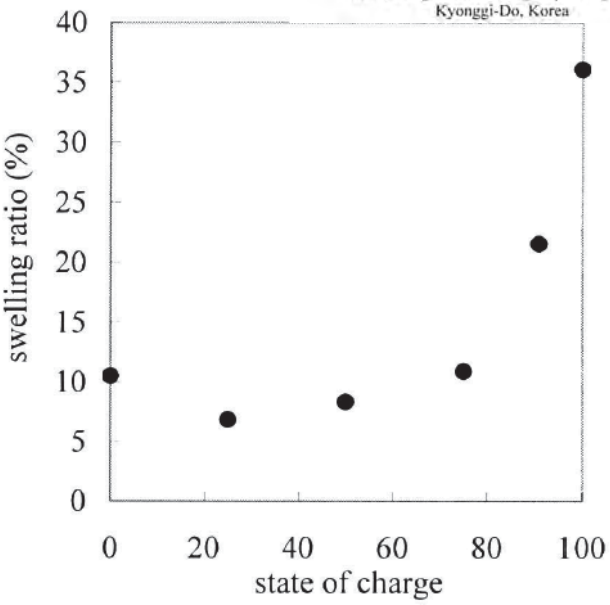


Fig. 1. The swelling ratio of the Li-ion batteries after storage for 4hrs at 90°C

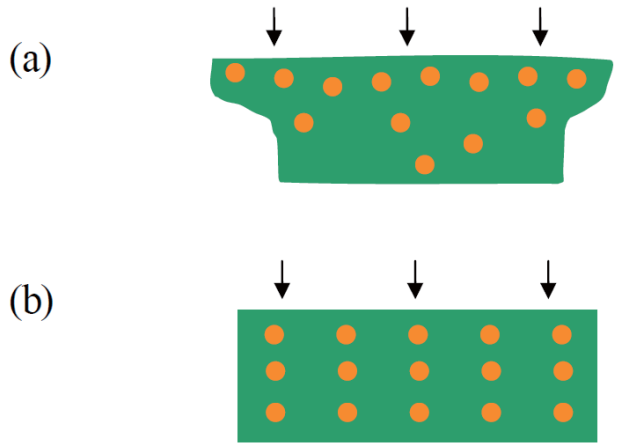
電極是有厚度與寬度的…
快充快放的為什麼有問題？

- Figure 2. 2.
  - (a)When the rate of discharging is high, the distribution of Li in the active particle is inhomogeneous, which causes a field of stress in the particle.
  - (b)When the rate of discharging is low, the distribution of Li in the particle is nearly homogenous, and the magnitude of the stress in the particle is negligible.

Thesis Advisors
Zhigang Suo, Joost J. Vlassak

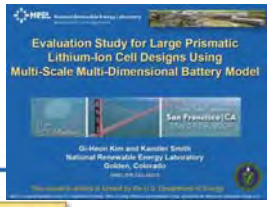
Author
Kejie Zhao

Mechanics of Electrodes in Lithium-ion Batteries



The arrows indicate the direction of Li insertion.

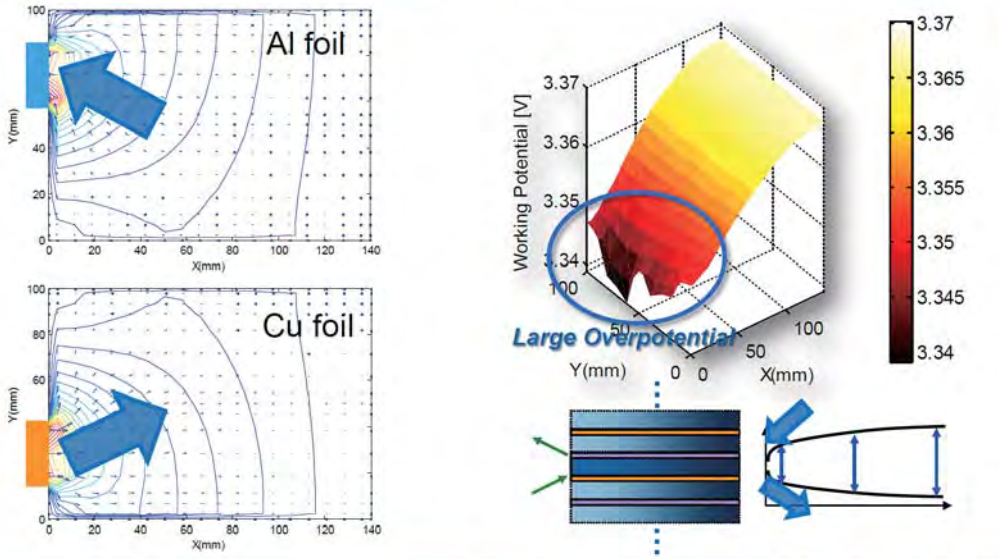
電化學反應需要時間，電流動也需要時間
快速充放電還有甚麼問題？



Electrical Response – 10C Discharge

Current density field at metal collector foils after 30 sec discharge at mid-plane

Working potential between electrode planes after 30 sec discharge at mid-plane



National Renewable Energy Laboratory 14 Innovation for Our Energy Future

堆疊方式也會有問題？

The Impact of Cell Geometries and Battery Designs on Safety and Performance of Lithium Ion Polymer Batteries

Soonho Ahn, Hyang-Mok Lee, Seung-Jin Lee, Youngsun Park, Cha-Hun Ku, Je Young Kim, Jae-Hyun Lee, Seok Koo Kim, and Jin Yeon Cho
Batteries R&D, LG Chemical Ltd./ Research Park
P.O.Box 61, Yu Song, Science Town
Daejon, 305-380, Korea

- The advantages we have found of flat-plate designs can be summarized as:
  - i) true flat shape that helps to keep the battery thickness uniform and thin,
  - ii) inherently higher energy densities due to lesser dead volume within the cell enclosure,
  - iii) lower cell impedance resulting from plurality of electrical contacts through electrode tabs.
- We also noticed for the stacked cells, the manner in which each cell is folded with separator materials dictates abuse safeties at elevated temperatures such as hot box and overcharge.
- During high temperature events, it was observed that short circuits that may occur around the electrode edges can trigger safety events more easily.
- Free stack structures without any folding options inevitably allow the separator materials to contract when exposed to shutdown temperatures.
- Although inherent thermal properties of electrolytes and electrode materials are important, cell designs must also be considered for safer lithium ion battery developments.

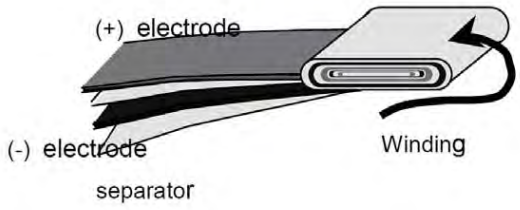


Figure 1. Conventional Flat Wound Jelly Roll Structure

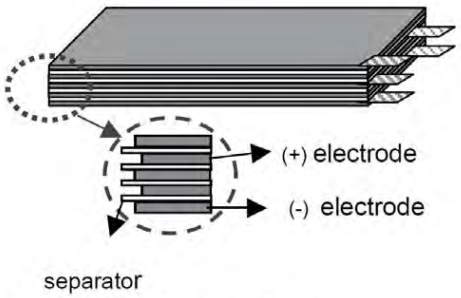
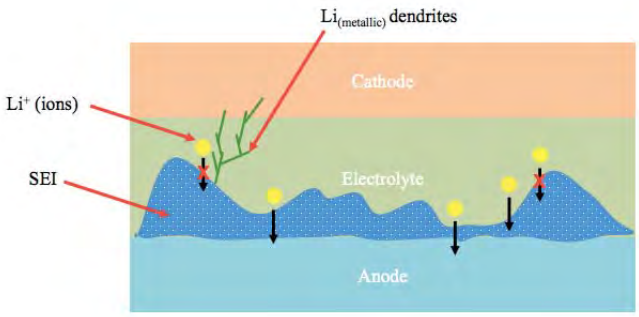


Figure 2. Plain Stacked-Electrode Structure

鋰離子電池的內短路關鍵
過度發展的固液介面（SEI）



https://areweanycloser.wordpress.com/2013/06/21/dendritic-lithium-and-battery-fires/

REF : DOT HS 811 573, Jan 2012, Chevy Volt Battery Incident

https://longtailpipe.com/wp-content/uploads/2012/01/burnt-chevy-volt1.jpg

Auxiliary Power Unit Battery Fire
Japan Airlines Boeing 787-8, JA829J
Boston, Massachusetts
January 7, 2013

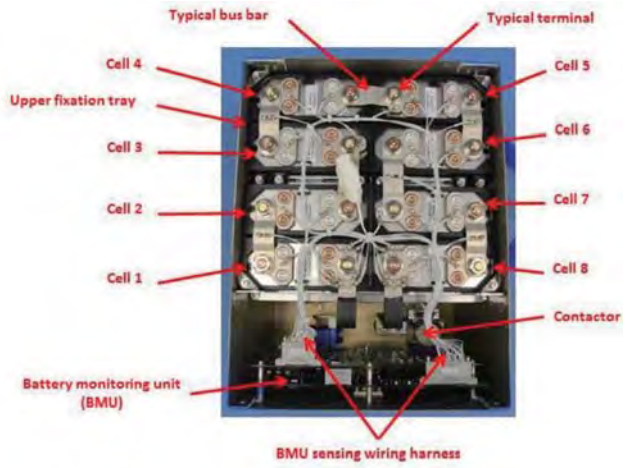


Figure 2. Main and APU exemplar battery.

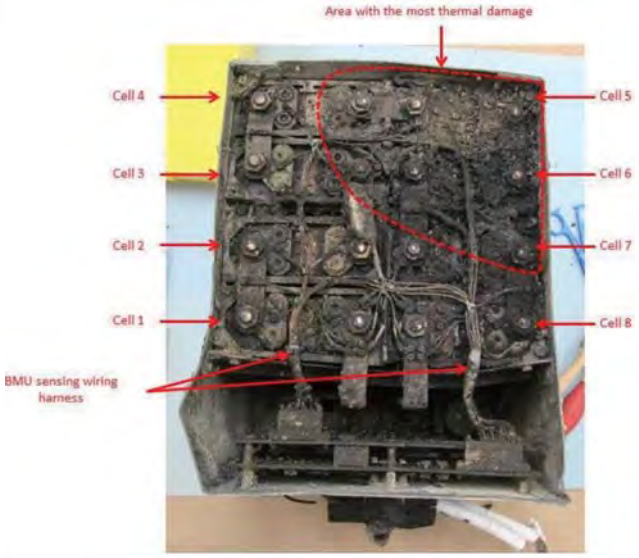
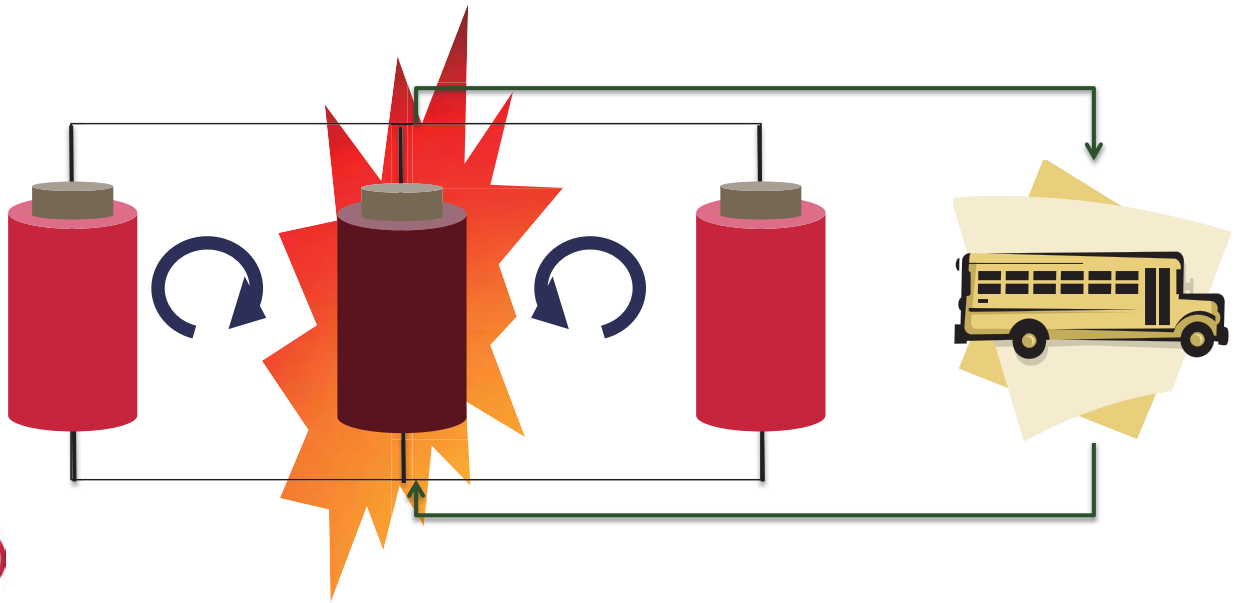


Figure 10. Thermal damage to battery.

大型電池組在完全沒通電與碰撞下可能自燃？

- 特性不匹配電池串並聯，造成內部迴路的而形成對某電池串的過充？



連接材料選不對，電化學鏽蝕就會產生！

Table of electrochemical potentials

Magnesium, magnesium alloys	Zinc, zinc alloys	80 tin/20 Zn on steel, Zn on iron or steel	Aluminium	Cd on steel	Al/Mg alloy	Mild steel	Duralumin	Lead	Cr on steel, soft solder	Cr on Ni on steel, tin on steel, 12 % Cr stainless steel	High Cr stainless steel	Copper, copper alloys	Silver solder, Austenitic stainless steel	Ni on steel	Silver	Rh on Ag on Cu, silver/gold alloy	Carbon	Gold, platinum	
0	0,5	0,55	0,7	0,8	0,85	0,9	1,0	1,05	1,1	1,15	1,25	1,35	1,4	1,45	1,6	1,65	1,7	1,75	Magnesium, magnesium alloys
	0	0,05	0,2	0,3	0,35	0,4	0,5	0,55	0,6	0,65	0,75	0,85	0,9	0,95	1,1	1,15	1,2	1,25	Zinc, zinc alloys
		0	0,15	0,25	0,3	0,35	0,45	0,5	0,5	0,6	0,7	0,8	0,85	0,9	1,05	1,1	1,15	1,2	80 tin/20 Zn on steel, Zn on iron or steel
			0	0,1	0,15	0,2	0,3	0,35	0,4	0,45	0,55	0,65	0,7	0,75	0,9	0,95	1,0	1,05	Aluminium
				0	0,05	0,1	0,2	0,25	0,3	0,35	0,45	0,55	0,6	0,65	0,8	0,85	0,9	0,95	Cd on steel
					0	0,05	0,15	0,2	0,2	0,3	0,4	0,5	0,55	0,6	0,75	0,8	0,85	0,9	Al/Mg alloy
						0	0,1	0,15	0,2	0,25	0,35	0,45	0,5	0,55	0,7	0,75	0,8	0,85	Mild steel
							0	0,05	0,1	0,15	0,25	0,35	0,4	0,45	0,6	0,65	0,7	0,75	Duralumin
								0	0,5	0,1	0,2	0,3	0,35	0,4	0,55	0,6	0,66	0,7	Lead
									0	0,05	0,15	0,25	0,3	0,35	0,5	0,55	0,6	0,65	Cr on steel, soft solder
										0	0,1	0,2	0,25	0,3	0,45	0,5	0,55	0,6	Cr on Ni on steel, tin on steel, 12 % Cr stainless steel
											0	0,1	0,15	0,2	0,35	0,4	0,45	0,5	High Cr stainless steel
												0	0,05	0,1	0,25	0,3	0,35	0,4	Copper, copper alloys
													0	0,15	0,2	0,25	0,3	0,35	Silver solder, Austenitic stainless steel
														0	0,15	0,2	0,25	0,3	Ni on steel
															0	0,5	0,1	0,15	Silver
																0	0,05	0,1	Rh on Ag on Cu, silver/gold alloy
																	0	0,5	Carbon
																		0	Gold, platinum

NOTE - Corrosion due to electrochemical action between dissimilar metals that are in contact is minimized if the combined electrochemical potential is below about 0.6 V. In the table the combined electrochemical potentials are listed for a number of pairs of metals in common use; combinations above the dividing line should be avoided.

電鍍材料選錯了，結果反而更糟？

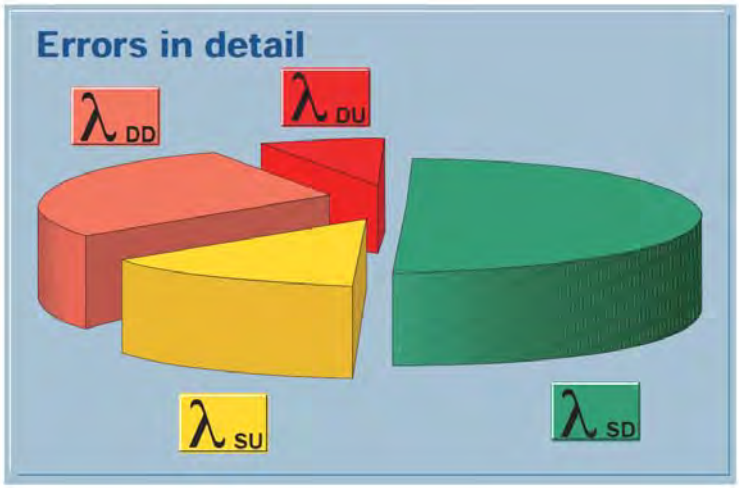
TABLE 4.8
Summary of Comparative Evaluation of Different Coating Materials for Aluminum-to-Copper Connections

Contact Pairs	Index
Aluminum (nickel-plated)—Copper (nickel-plated)	0.7
Aluminum (copper-plated)—Copper (bare)	1.0
Aluminum (bare)—Copper (nickel-plated)	1.3
Aluminum (bare)—Copper (silver-plated)	2.0
Aluminum (bare)—Copper (bare)	2.4
Aluminum (bare)—Copper (tin-plated)	2.7

汰役電池應該檢測哪些項目？

Source: http://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2012/Nov/electrification/1114_reuse.html

沒看到不代表沒有事？！
電池沒有事不代表電池組沒有事…



λ_{SD} = safe detected failure rate

λ_{SU} = safe undetected failure rate

λ_{DD} = dangerous detected failure rate

λ_{DU} = dangerous undetected failure rate

健康與壽命狀態要看哪幾項？

An Accurate Electrical Battery Model Capable of Predicting Runtime and I–V Performance

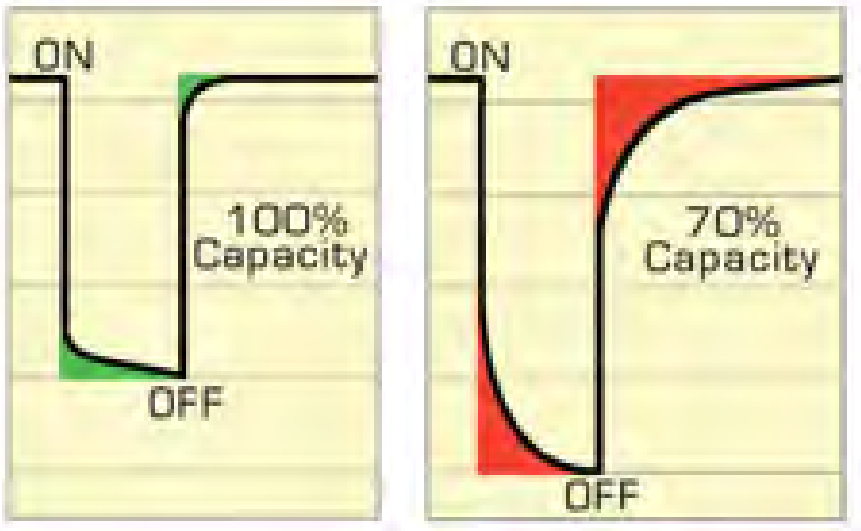
Min Chen, *Student Member, IEEE*, and Gabriel A. Rincón-Mora, *Senior Member, IEEE*
Georgia Tech Analog and Power IC Design Lab

An accurate, intuitive, comprehensive electrical model has been proposed to capture the entire dynamic characteristics of a battery, from nonlinear open-circuit voltage, current-, temperature-, cycle number-, and storage time-dependent capacity to **transient response**.

怎麼看差異？

Figure 1: Electrochemical dynamic response

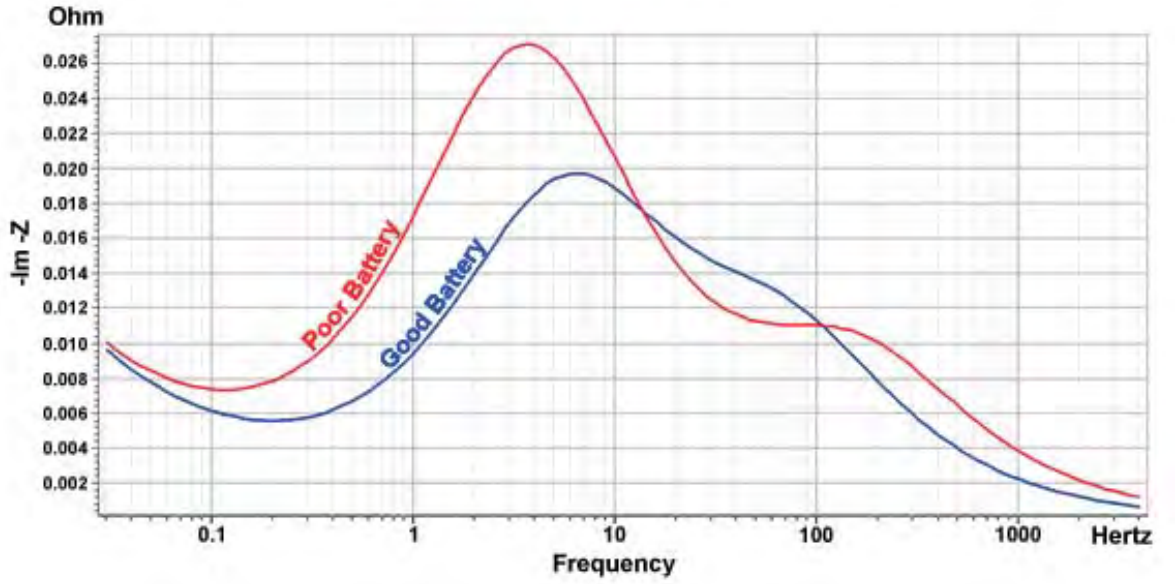
- The electrochemical dynamic response measures the ion flow between the positive and negative plates. A strong battery recovers quickly from an attack whereas a weaker pack behaves more sluggish



用甚麼頻率來看比較好？

Figure 2: Frequency scan of a good and weak battery

- Differences in impedances are most visible below 10Hz. The horizontal scale is logarithmic to condense the frequency range.



但是電池串並聯之後，失效機率是疊加或降低？

- 同樣為百萬分之一的失效率的電池一千顆”串”聯在一起時
- 失效機率會變成...
- 同樣為百萬分之一的失效率的電池一千顆”並”聯在一起時
- 失效機率會變成...

百萬分之一的一千次方？

或

一千分之一？

電池組又要看甚麼呢？
失效防護對策還有哪些？

Proceedings from
3rd International Conference on
Fires in Vehicles - FIVE 2014
October 1st-2nd, 2014
Berlin, Germany
Edited by Petra Andersson and Björn Sundström

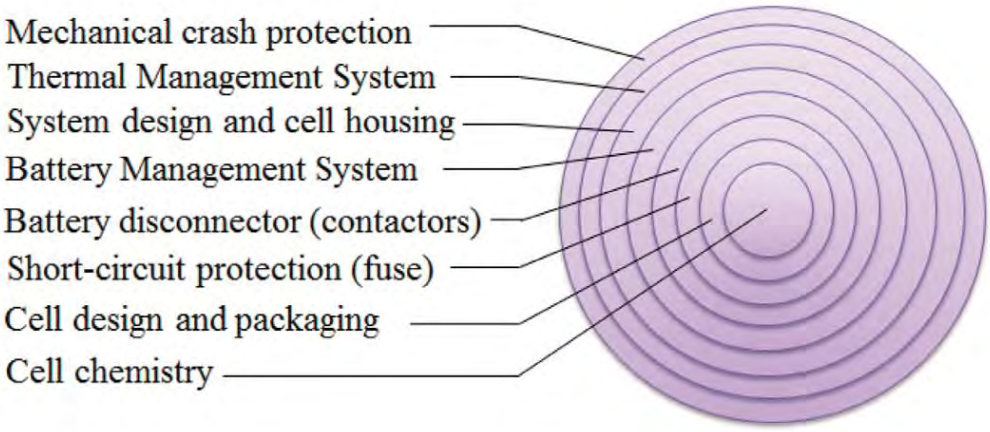
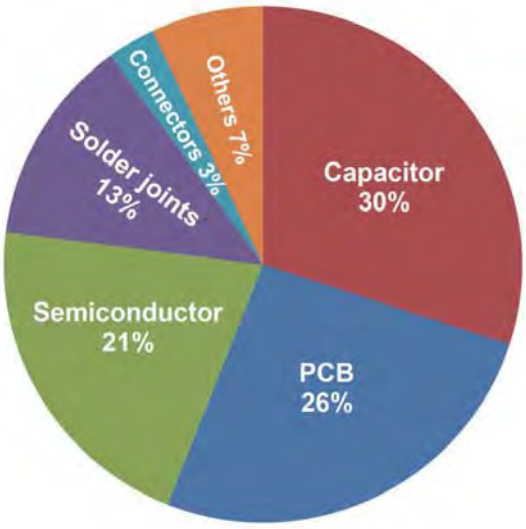


Figure 15 *The safety-onion showing examples of layer by layer of different safety actions that can be used to establish a safe battery system in electrified vehicles.*

控制系統也有耐用年限
看看電子產品失效機率分佈…



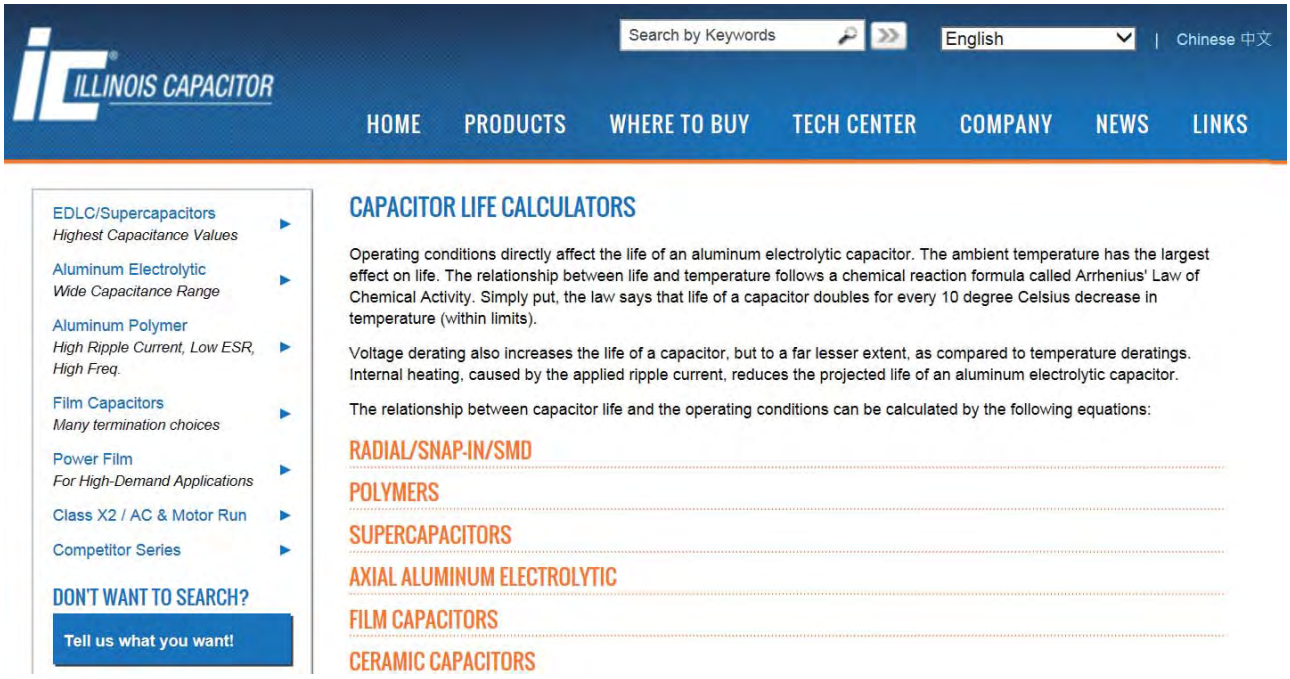
(www.abb.com)

(http://www.alibaba.com)

Failure root causes distribution for power electronic systems*
(% may vary for different applications and designs)

*Data sources: Wolfgang E., "Examples for Failures in Power Electronics Systems," in *EPE Tutorial 'Reliability of Power Electronic Systems'*, April 2007.

電容壽命怎麼檢測/推測？



Source: http://www.illinoiscapacitor.com/tech-center/life-calculators.aspx

電路板壽命怎麼推測？眼圖？

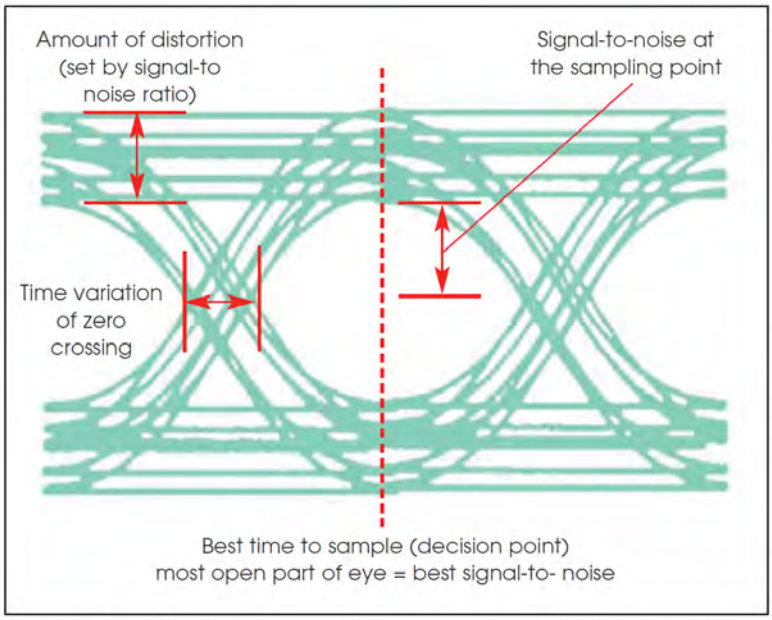
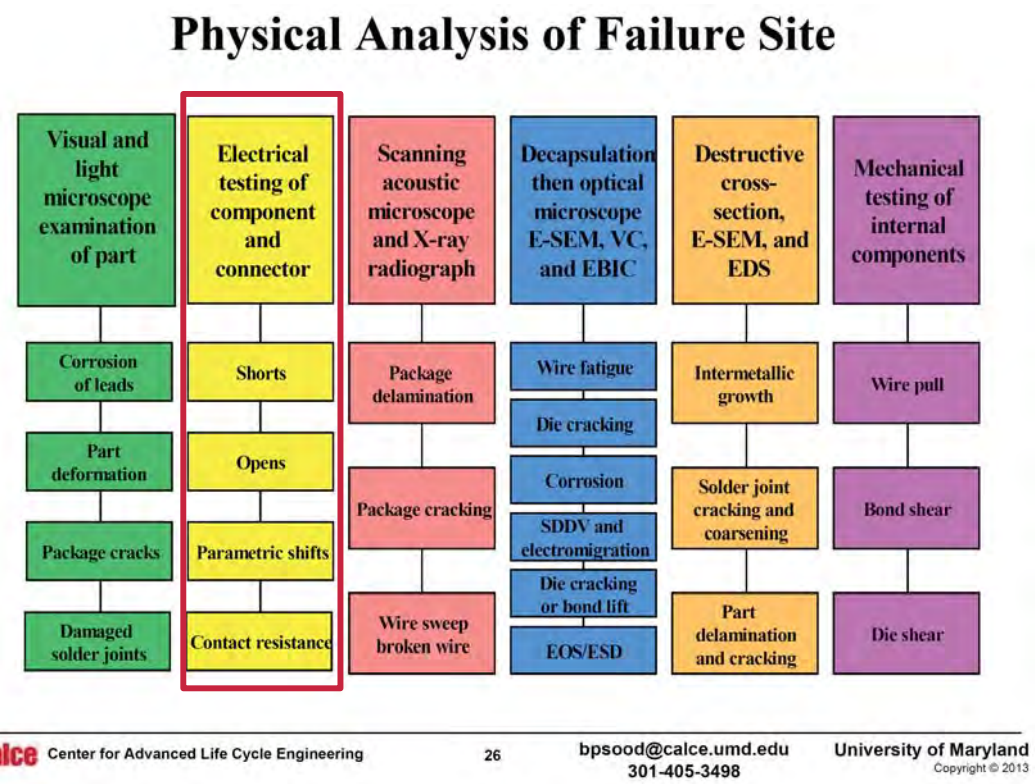


Figure 3 · Basic information contained in the eye diagram. The most important are size of the eye opening (signal-to-noise during sampling), plus the magnitude of the amplitude and timing errors.

印刷電路板怎麼檢測？



接點壽命怎麼測？
溫度變化可以看甚麼…

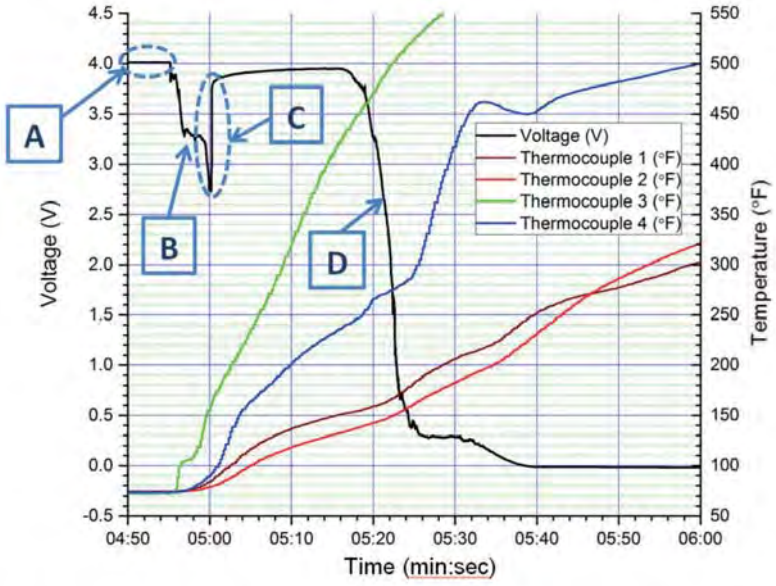


Figure 15. Results of cell-level internal short circuit abuse test.

Note: The preceding paragraph describes each region depicted in this figure. The thermocouples used to measure cell temperature were typically placed at the cell's copper (negative) rivet (thermocouple 1), the aluminum (positive) rivet (thermocouple 2), 0.2 in from the internal short circuit initiation point (thermocouple 3), and 0.1 in from the vent disc (thermocouple 4).

不良銲點，溫度會逐漸上升

Jay Johnson
Ward Bower
Michael Quintana
Sandia National Laboratories
P.O. Box 5800 MS0352
Albuquerque, NM 87185
e-mail: jjohns2@sandia.gov

Electrical and Thermal Finite Element Modeling of Arc Faults in Photovoltaic Bypass Diodes

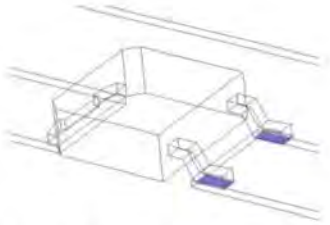


Fig. 13: Location of contact resistance from corrosion.

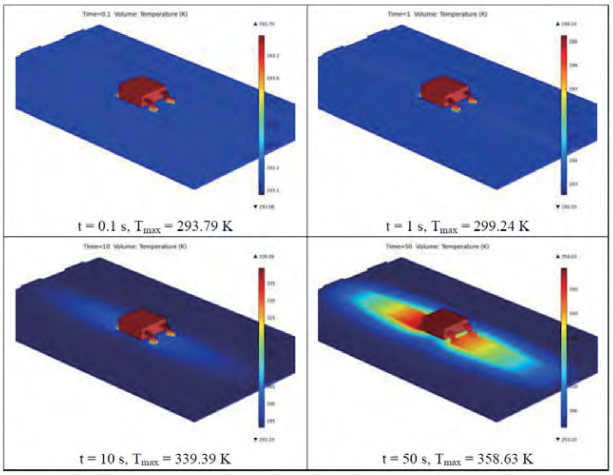
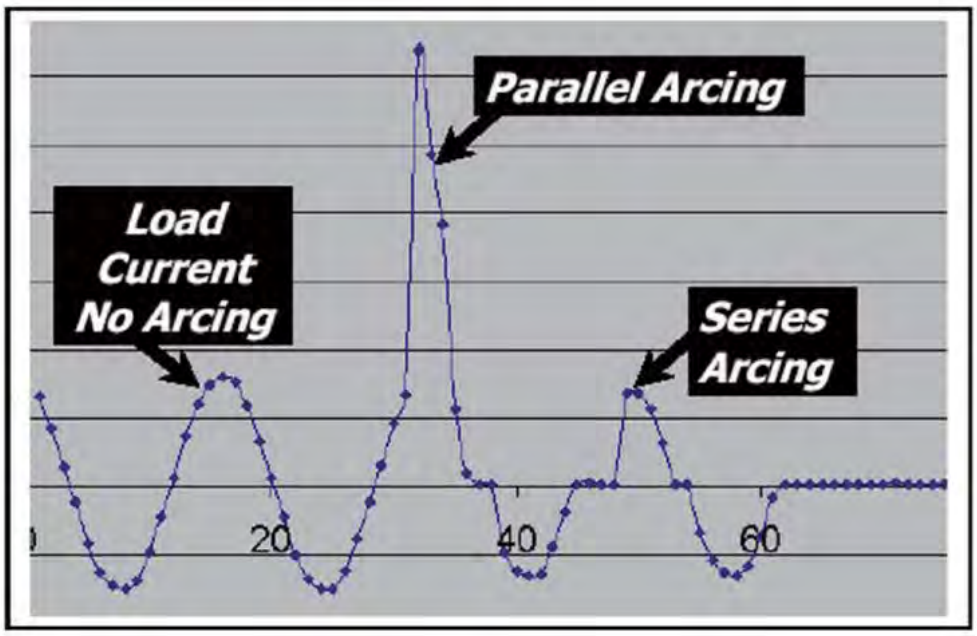


Fig. 11: Temperature distribution from Joule and internal heating of the diode for different simulation times.

不良銲點，電波波形會失真

Arcing Faults / 电弧故障



不良銲點，會有循環的溫度變化…

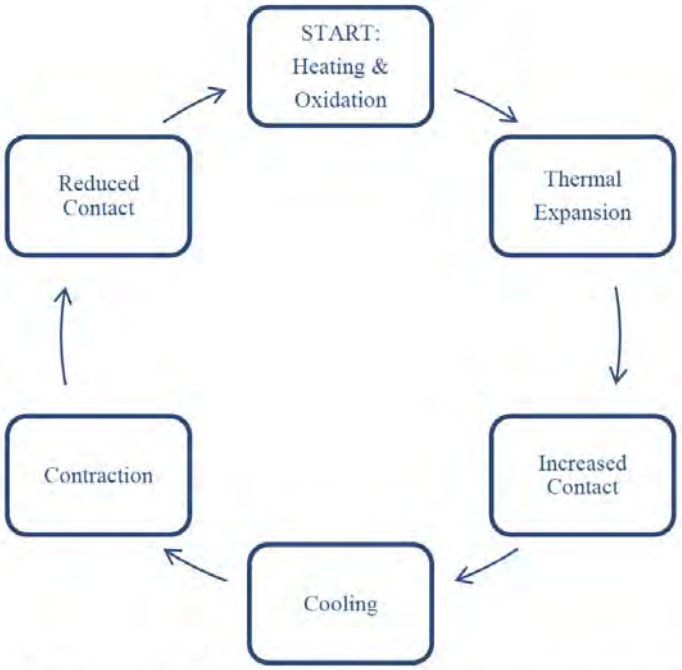


Figure 2-38. Potential heating and cooling cycle for a connection showing frequent oscillations in temperature.

不良連接，跨接電阻上升會使電路溫度上升

Statement of the the Issues

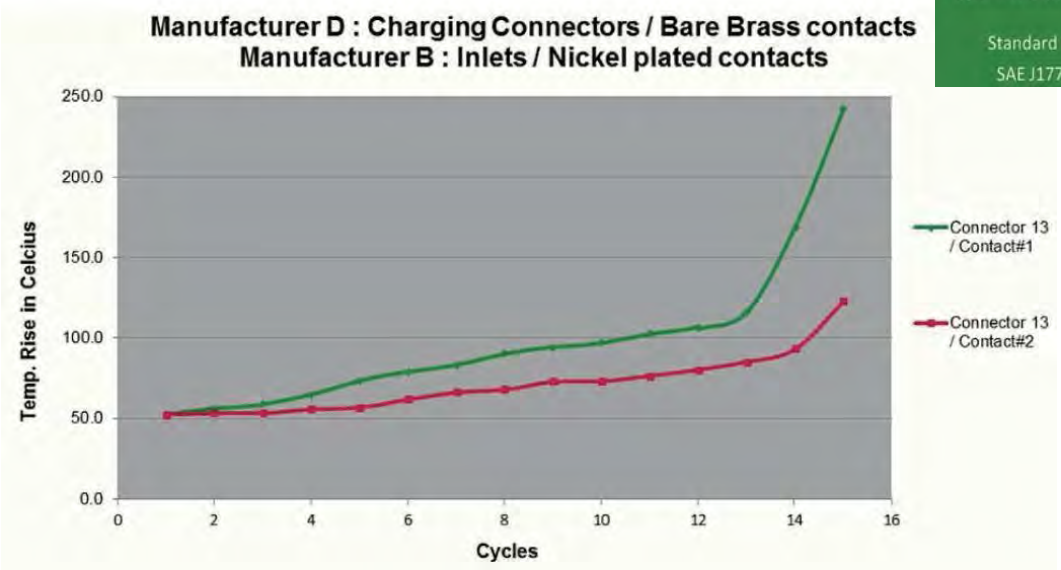
Supporting information: Test Specifications

4. Test Data

Electric Vehicle Charging Connectors and Inlets

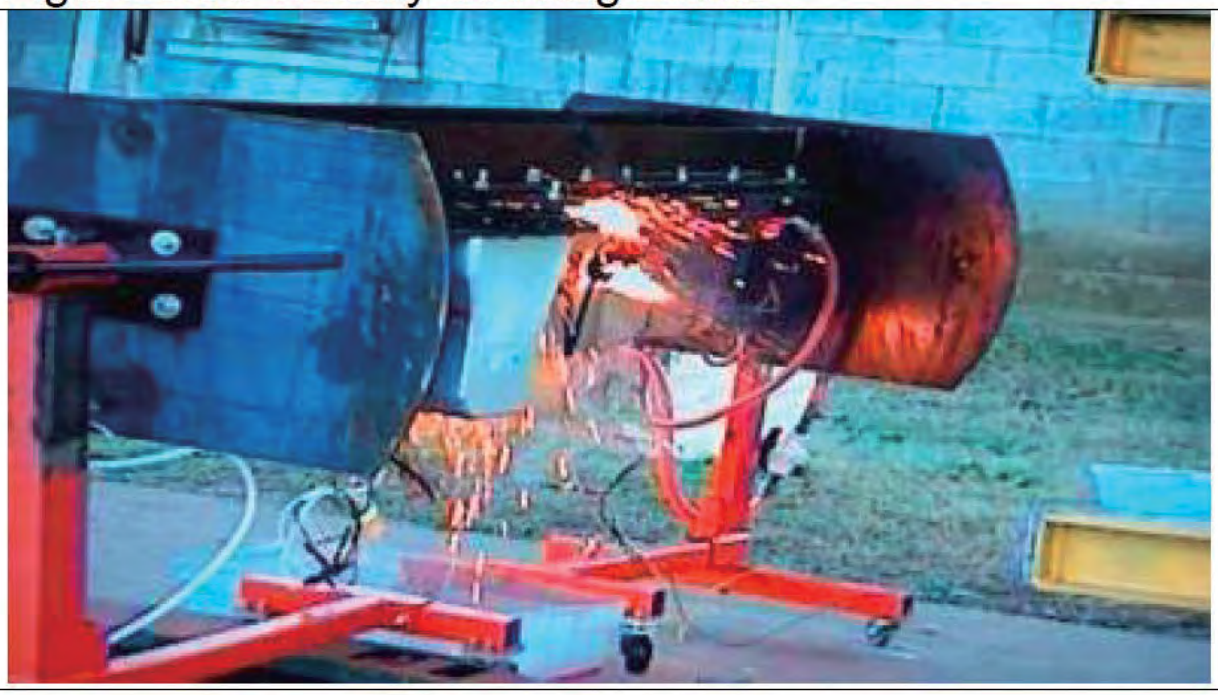
Standard Improvement

SAE J1772 & UL2251



Pack可以直接做測試嗎？

Figure 5.04 Battery 3 Arcing Event



總結

- 汰役電池安全風險，不只在電池芯，也在電池組。
- 汰役電池組的非破壞與動態檢測，是成功的關鍵。
- 使用資料的管理，能夠減少檢測的風險。
- 講了老半天，標準在哪裡？

Q & A

Thank You.

關於 UL

- UL 是一家全球知名從事安全科學事業的公司，享譽一百多年歷史。
- UL 服務機構遍佈全球逾 100 個國家，擁有超過 11,000 多名專業員工。
- UL 持續研究發展和制定標準，以滿足不斷演繹的安全需求。
- UL 認證、檢測/驗證、測試、檢驗、稽核、諮詢培訓服務等詳情，請瀏覽 www.UL.com。

CHEN TECH ELECTRIC

SOH Evaluation Solution

YM Huang

承德科技 CHEN TECH ELECTRIC

CHEN TECH ELECTRIC

Outline

- What does SOH mean?
- Modeling
- SOH Evaluation Suit
- Case Study

承德科技 CHEN TECH ELECTRIC

CHEN TECH ELECTRIC

What does SOH mean ?

承德科技 CHEN TECH ELECTRIC

CHEN TECH ELECTRIC

SOH Definition

SOH :State-Of-Health

“ The State of Health is a” measurement “ that reflects the general condition of a battery and its ability to deliver the specified performance compared with a fresh battery. ”

The Eletrocpaedia

$$\mathrm{SOH} \equiv \frac{\mathrm{AHC}_{\mathrm{Aged}}}{\mathrm{AHC}_{\mathrm{Nominal}}}$$

“ An Improved Battery Characterization Method Using a Two-Pulse Load Test ” IEEE TRANSACTIONS ON ENERGY CONVERSION , 2008

承德科技 CHEN TECH ELECTRIC

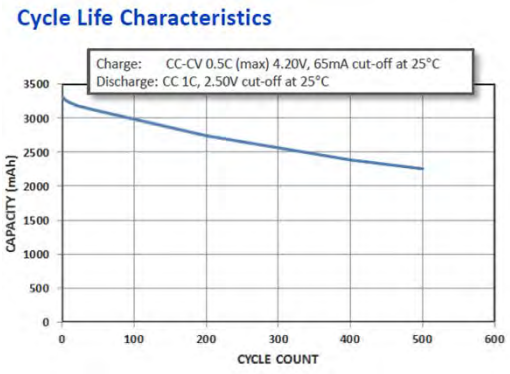
Parameters Related to SOH

SOH = A weighted summary of specified parameters

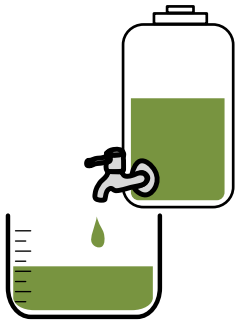
- Capacity
- Voltage
  - Open Circuit Voltage
  - Recovery Voltage
- Internal Resistance
- Self-Discharge
- Number of Used Cycle
- …

Capacity

- Releasable /Available (Electric Charge)Capacity
- Releasable /Available Energy

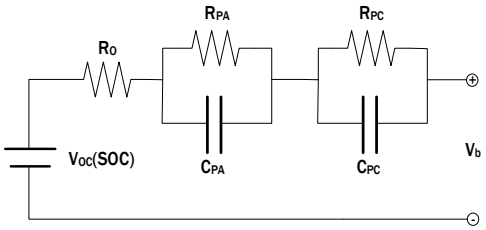


Panasonic 18650B Datasheet



Voltage (Open Circuit Voltage)

- Open Circuit Voltage



Voltage (Voltage Recovery)

- Voltage Recovery

" From a theoretical point of view, the voltage relaxation could be used as an indirect measure of degree of lithiation in the cathode and anode of a Lithium-ion battery. "

" The $V_{recovery}$ evolution has fast, medium and long time memory relations with current, SOC and voltage conditions previous to this transitory state. "

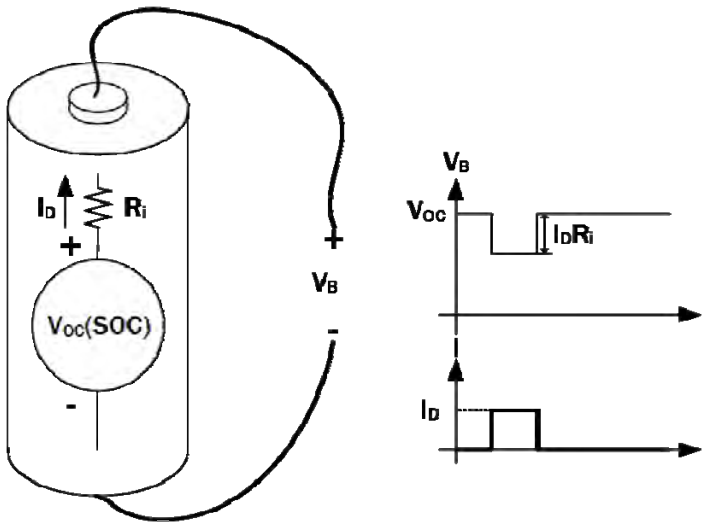
" PHEV battery ageing study using voltage recovery and internal resistance from On-board data "
IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY , 2015

Internal Resistance

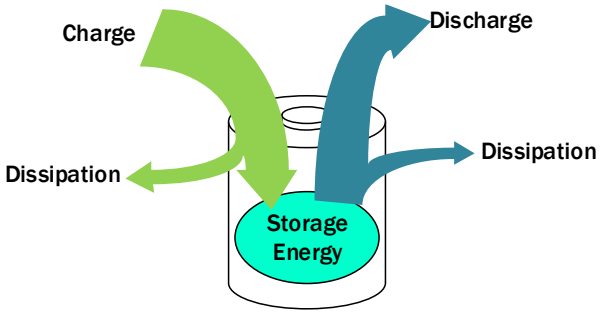
- **Ohm's Law**
  - VDA Current Step Method
  - ISO Current Step Method
  - Current-off Method
  - Switching Current Method
- **Joule's Law**
  - Energy Loss Method
  - Quasi Adiabatic Battery Calorimeter
- **ACIR**
  - Fixed Frequency AC Internal Resistance
  - Impedance Spectroscopy

" Comparison of Several Methods for Determining the Internal Resistance of Lithium Ion Cells "
Sensors , 2010

Ohm's Law

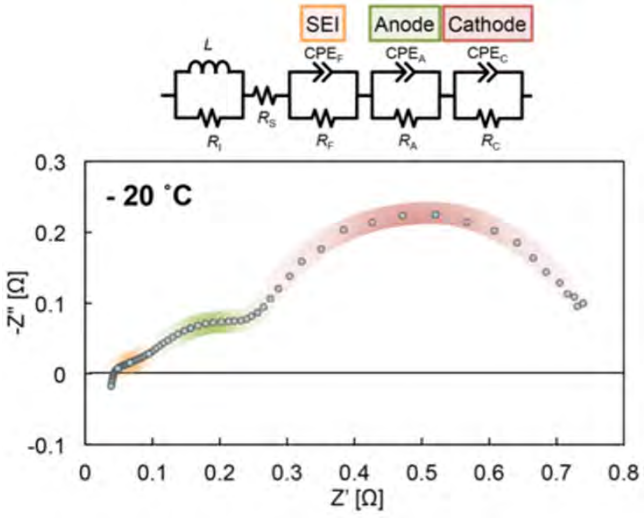


Joule's Law



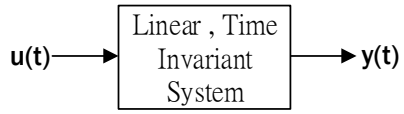
- Energy Loss Method : The difference of energy between Charging and Discharging with the same amount of carriers.
- Quasi Adiabatic Battery Calorimeter : Dissipation Heat

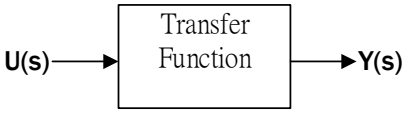
ACIR



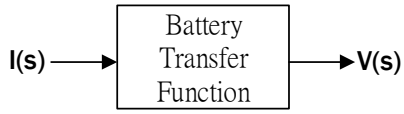
" AC impedance analysis of lithium ion battery under temperature control. "
Journal of Power Sources , 2012

Transfer Function





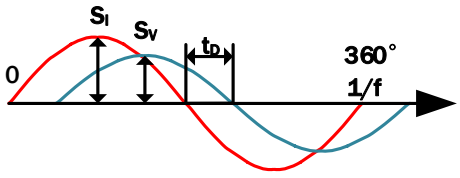
$$G(s)=\frac{Y(s)}{U(s)}$$



$$G(s)=\frac{V(s)}{I(s)}$$

$$Y(\omega)=|G(\omega)|U(\omega+\angle(G(\omega)))$$

Measure ACIR

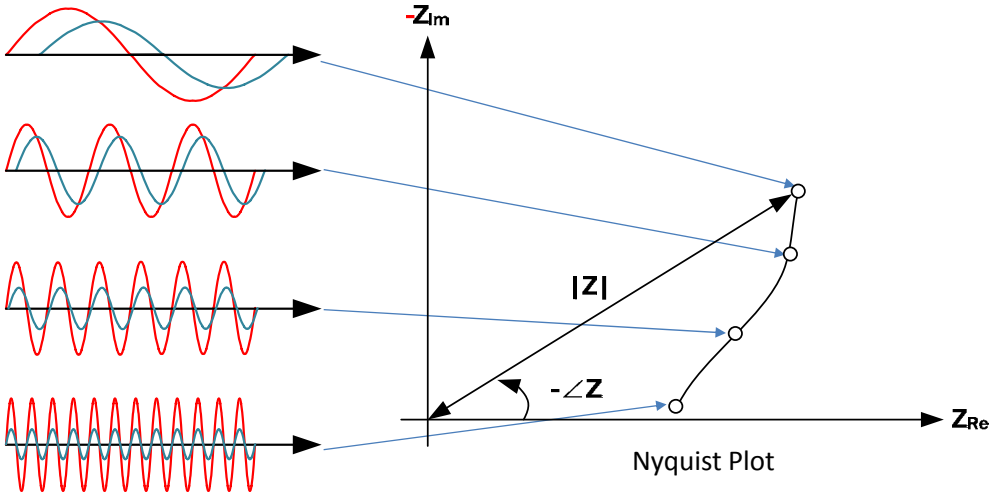


Apply sinusoid current with amplitude :S_I and frequency : f to battery, and observe the response voltage with the same frequency.

$$|Z|=\frac{S_V}{S_I} \qquad \angle Z=-\frac{t_D}{1/f}360°$$

CHEN TECH ELECTRIC

Spectroscopy

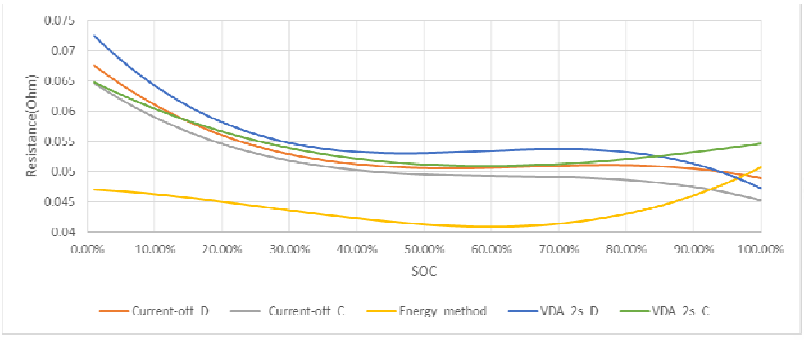


Nyquist Plot

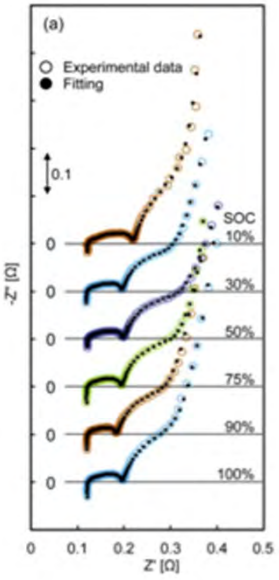
承德科技 CHEN TECH ELECTRIC

CHEN TECH ELECTRIC

Internal Resistance vs SOC



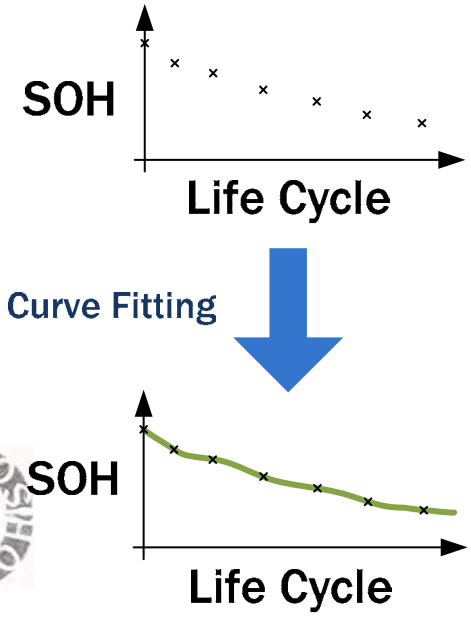
From CTE



" Proposal of novel equivalent circuit for electrochemical impedance analysis of commercially available lithium ion battery " , *Power Sources* , 2012

Modeling

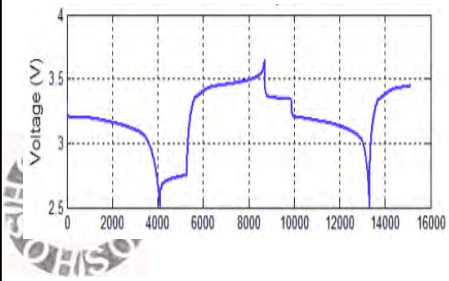
Basic Principle

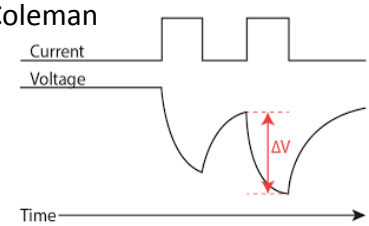


- **Measuring** the SOH parameters from sample batteries under specific condition
- **Modeling** discrete / continuous function based on the collected data
- **Evaluating** the SOH of used EV batteries

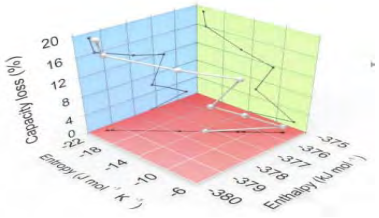
Measurement Methods

Full Cycle Measurement	Rapid Measurement	Accurate Measurement
Using IEEE 1188-2005 based fully charge-discharge cycle to collect **V, I, T** for SOH calculation	Using efficient way to collect **V, I, T variation** for SOH calculation. E.g., Two-pulse method by Dr. Marie Coleman	Using special machine to collect **specified information like Entropy, Enthalpy, or other EIS parameters** for SOH calculation





From: IEEE PESC 2006



From: DR. Richid Yazami

Modeling Methods

Line Regression	Higher-Order Polynomial	Cubic Spline
• Simple model • Low Accuracy in most situation	• Suitable order builds approximate model • The higher order needs to solve the bigger matrix	• Suitable solution for polynomial model degree under 3 • Model 1st and 2nd Order differential should continuous at fitting points

Linear Combination of Known Functions	Lagrange Interpolation	Lagrange Interpolation (Chebyshev Roots)
• Accuracy very depends on prescribed functions	• Model bounds to pass fitting points • Boundary region Accuracy is lower than middle region	• Decrease and average region error of Lagrange interpolation

Lagrange Interpolation

Given a set of K+1 data points$(X_0 , Y_0) , (X_1 , Y_1) \ldots (X_K , Y_K)$

Linear combination of Lagrange polynomial: $L(X) := \sum_{j=0}^{K} Y_j \ell_j$

Lagrange polynomial:

$$l_j := \prod_{\substack{0 \le m \le K \\ m \ne j}} \frac{X - X_m}{X_j - X_m} = \frac{X - X_0}{X_j - X_0} \cdots \frac{X - X_{j-1}}{X_j - X_{j-1}} \frac{X - X_{j+1}}{X_j - X_{j+1}} \cdots \frac{X - X_K}{X_j - X_K}$$

The resulting polynomial is more accurate in the middle of the interpolation range than the region near the boundary.

Chebyshev Roots

Lagrange interpolation Error:

$$E_N(X) = \frac{f^{(N+1)}(\xi)}{(N+1)!}(X - X_0)(X - X_1)\ldots(X - X_{N+1})$$

In order to minimize $\left|(X - X_0)(X - X_1)\ldots(X - X_{N+1})\right|$

Choose Chebyshev points $X_n = \cos\left(\frac{K + \frac{1}{2} - n}{K}\pi\right)$ n=1,2,3...K

Linear transformation $\frac{X - (-1)}{1 - (-1)} = \frac{Z - a}{b - a}$ $X \in [-1,1]$ $Z \in [a,b]$

$$Z_n = \frac{1}{2}\left[(b - a)\cos\left(\frac{K + \frac{1}{2} - n}{K}\pi\right) + a + b\right]$$

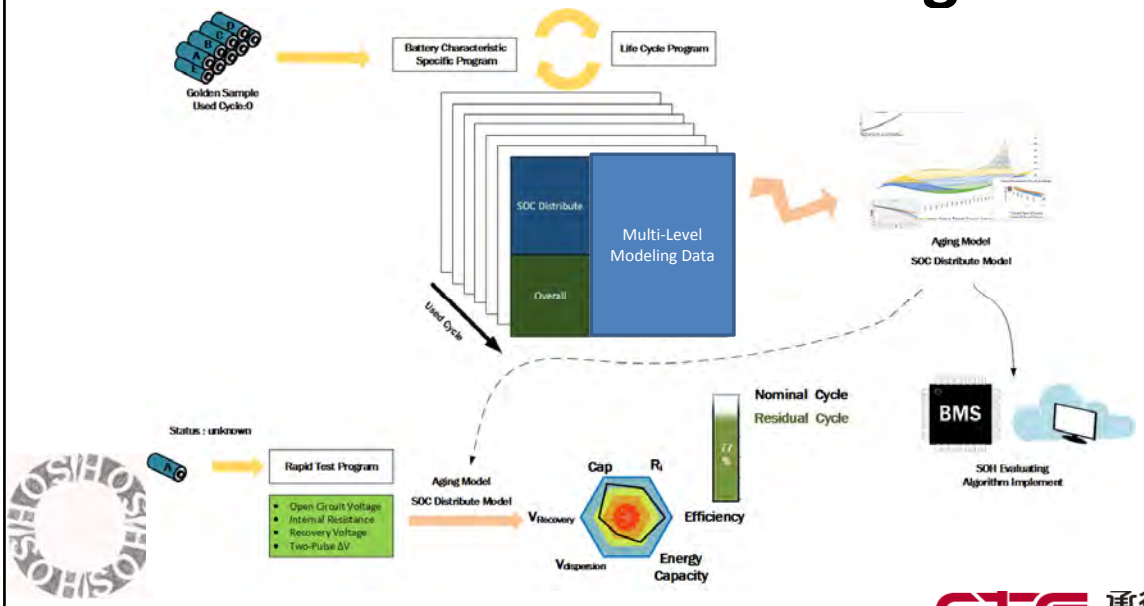
CHEN TECH ELECTRIC

SOH Evaluation Suite

承德科技 CHEN TECH ELECTRIC

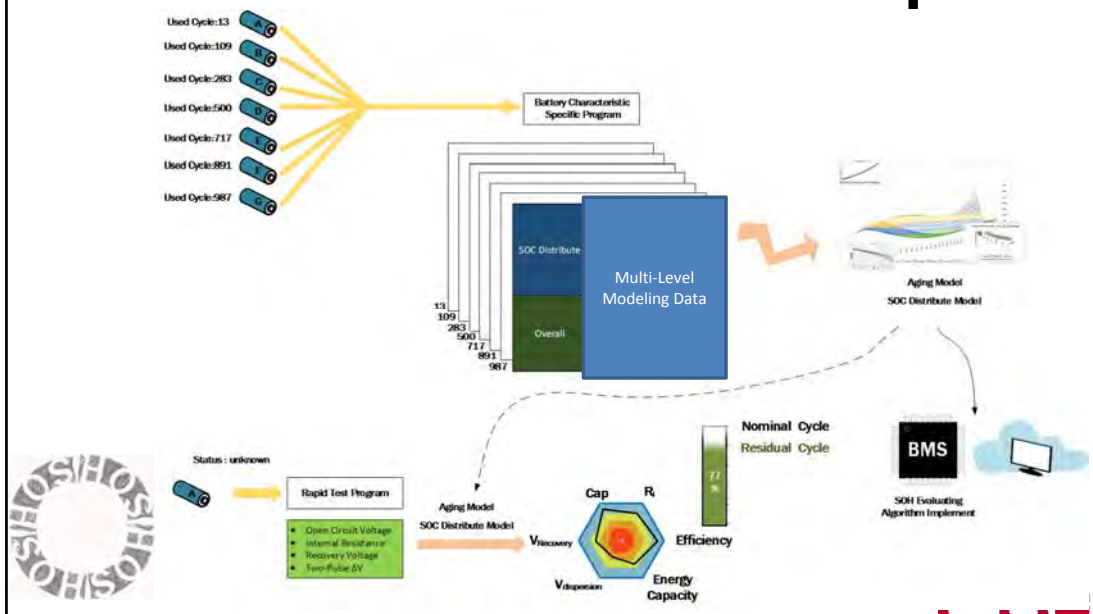
CHEN TECH ELECTRIC

Ideal SOH Evaluating

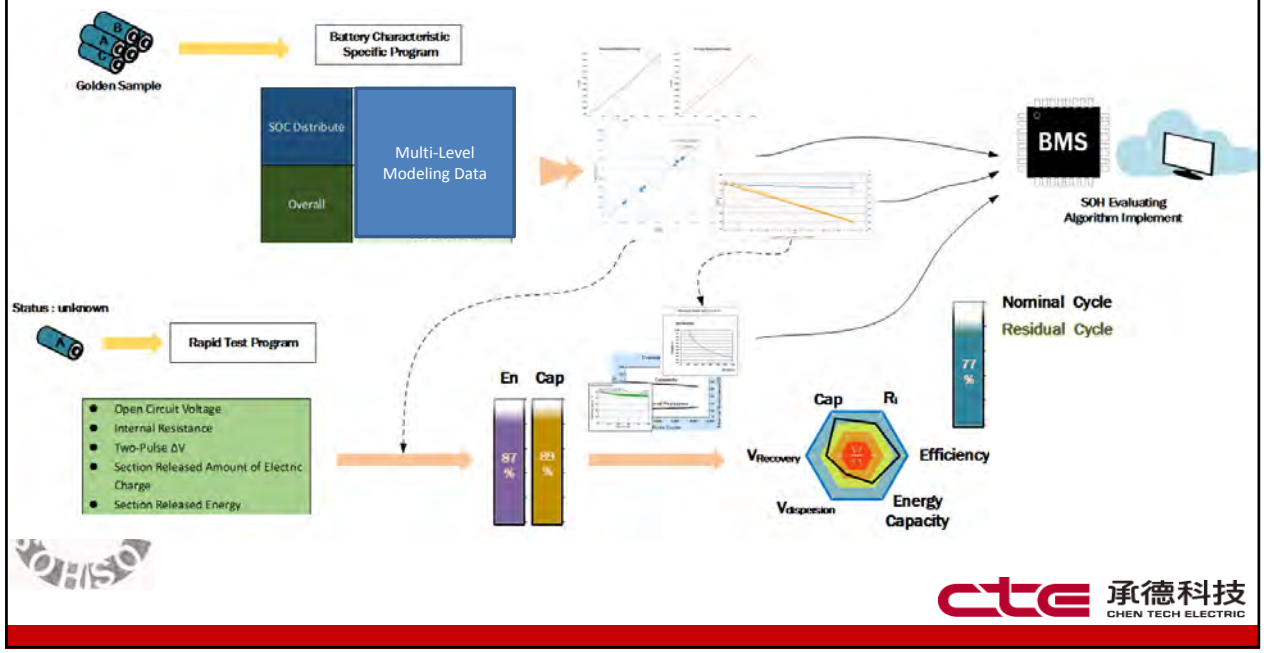


承德科技 CHEN TECH ELECTRIC

Preconditioned Sample



Datasheet Based Model



CHEN TECH ELECTRIC

Rapid Test Measure Error

$$\text{Capacity}_{eva} = \frac{\text{Current}}{\text{Crate}_{eva}} = \frac{\text{Current}_{real} + \text{Current}_{Error}}{\text{Crate}_{real} + \delta V_{Error}} = \frac{\text{Capacity}_{real} + \frac{\text{Current}_{Error}}{\text{Crate}_{real}}}{1 + \frac{\delta V_{Error}}{\text{Crate}_{real}}}$$

$$\text{Capacity}_{error} = \text{Capacity}_{eva} - \text{Capacity}_{real} = \frac{\text{Current}_{Error} - \delta V_{Error}\text{Capacity}_{eva}}{\text{Crate}_{real}}$$

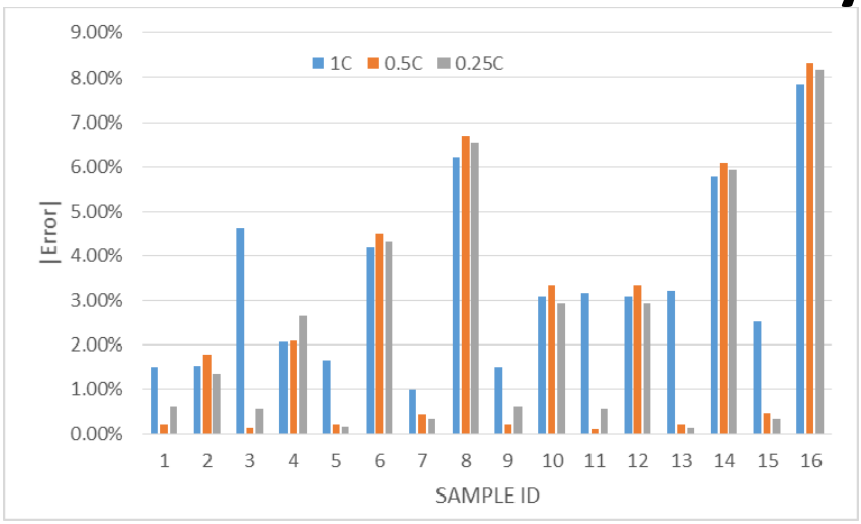
$$= \text{Capacity}_{eva}\left(\frac{\text{Current}_{Error}}{\text{Crate}_{real}\text{Capacity}_{eva}} - \frac{\delta V_{Error}}{\text{Crate}_{real}}\right)$$

Test sample	Equipment Accuracy	±F.S 0.02%	±F.S 0.1%	±F.S 0.2%	Equipment Accuracy	±F.S 0.02%	±F.S 0.1%	±F.S 0.2%
NCR18650B	Crate(Hr^{-1})	Mean error			Crate(Hr^{-1})	MAX error		
Estimation error	1	5.76%	7.58%	9.98%	1	11.78%	14.52%	18.14%
7%	0.75	5.91%	8.37%	11.65%	0.75	12.00%	15.71%	20.68%
Crate vs ΔV Ratio	0.5	6.21%	9.98%	15.21%	0.5	12.45%	18.14%	26.07%
5.1	0.25	7.12%	15.21%	27.87%	0.25	13.83%	26.07%	45.42%

承德科技 CHEN TECH ELECTRIC

CHEN TECH ELECTRIC

NCR18650B SOC:40% Verify

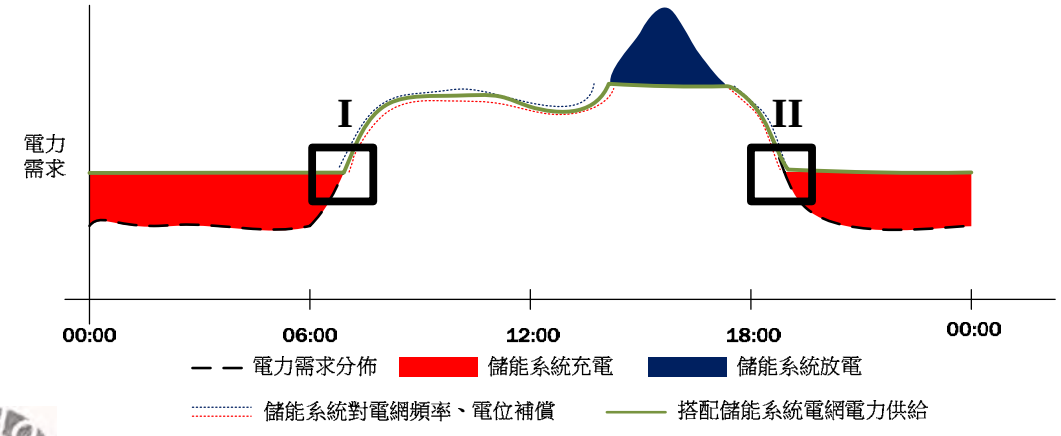


From CTE

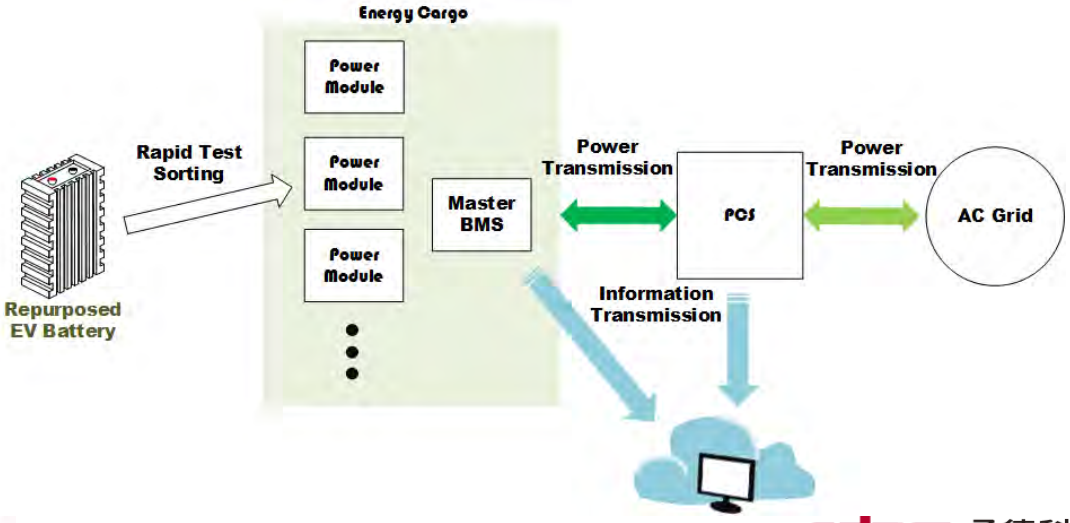
承德科技 CHEN TECH ELECTRIC

Case Study

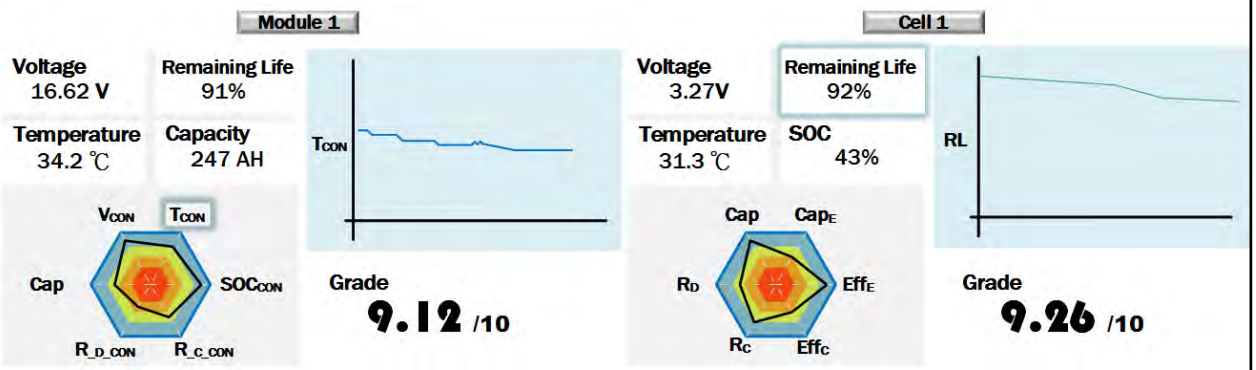
Load Leveling



Repurposed EV Battery Enabled Energy Storage System



Cell/Module Information



CHEN TECH ELECTRIC

Q&A

Thank you for your Attention!

承德科技 CHEN TECH ELECTRIC

快來掃描我！

掃描QRcode上 承德科技官網 或
前瞻電池研究與測試技術交流平台
FB按讚 獲取業界相關資訊

承德科技 CHEN TECH ELECTRIC

for further information
www.chentech.com.tw

■TAIPEI, TAIWAN
1F, NO.27, LN.61, SEC.1, GUANGFU RD.,
SANCHONG DIST., NEW TAIPEI CITY 24158,
TAIWAN

: sales@chentech.com.tw
: +886-2-22783825
: +886-2-22783926