Evaluation Of EV Battery Life

& Characteristic Simulation

Tracy Chou
www.itechate.com

CONTENTS

Batteries-an important role of electric transportation

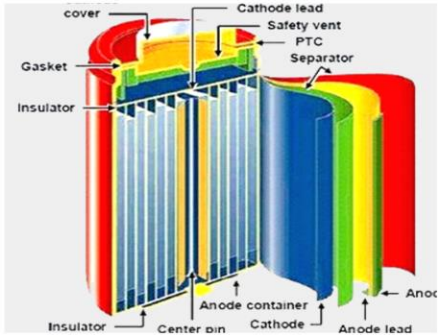
Li-Ion battery

Fuel cell

EV battery composition

- The focus of battery testing is different at different stages.
- The cycle life test is the most basic one for battery performance evaluation.

Battery Cell



Resistance Sorting (Chemistry)

Good cells with consistent internal resistance can be assembled into a battery module.

Battery Modules

capacity Sorting

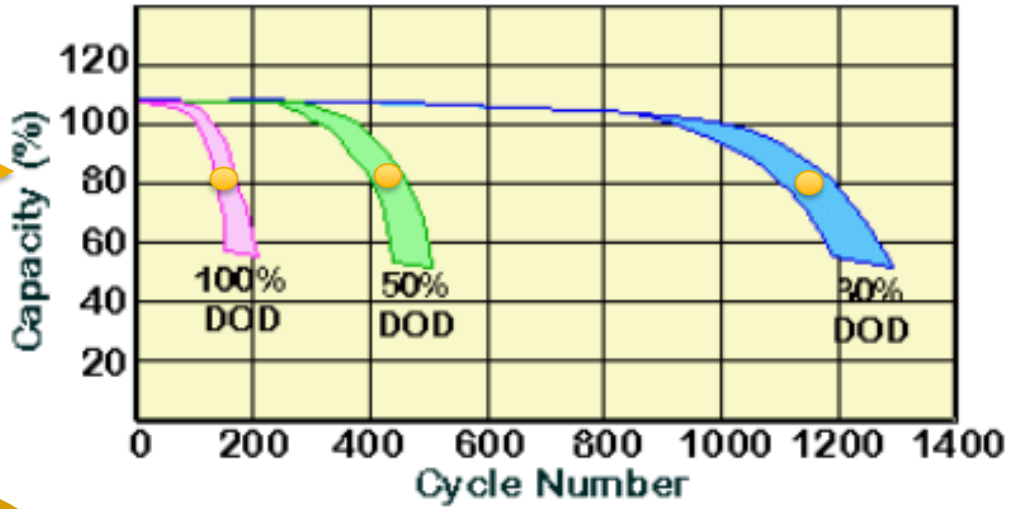
Battery modules are assembled in series and parallel to form larger battery packs.

Battery Pack

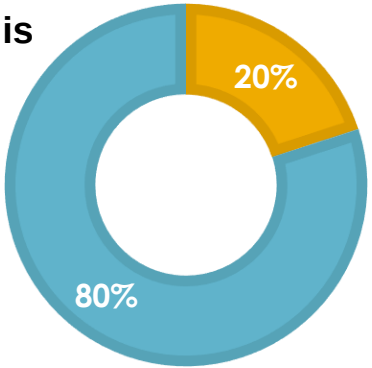
Application matching

Can the battery work well ?

EV battery – Cyclic Life



20% capacity attenuation is generally considered to be the end of EV battery life.



E.g. **Ternary lithium battery**

- Full battery life range : 400-500 km
- Cycle number : 500
- Total mileage : 200,000-250,000 km
- Car ≥10 years (travel 10,000-20,000 km/year)

- **Battery cell design /chemistry**
  - Aging of battery materials, chemical reactions
- **Battery integrated system design**
  - BMS, mechanical connection, cooling system

- **Environment**
  - Temperature/ humidity /vibration
- **Use of EV**
  - Charging / roading condition

ITECH

Why does a battery die?

How to evaluate the performance and life cycle of EV batteries -ISO12405

EV Battery Test Standards

INTERNATIONAL STANDARD

ISO 12405-4

First edition
2018-07

Electrically propelled road vehicles — Test specification for lithium-ion traction battery packs and systems —

Part 4:
Performance testing

Véhicules routiers à propulsion électrique — Spécifications d'essai pour packs et systèmes de batterie de traction aux ions lithium —

Partie 4: Essais de performance

Test Items

General tests (Clause 6)

- Pre-conditioning cyles (Clause 6.1)
- Standard cycle (Clause 6.2)
- Standard Discharge (Clause 6.2.2.2)
- Standard Charge (Clause 6.2.2.3)

Performance tests (Clause 7)

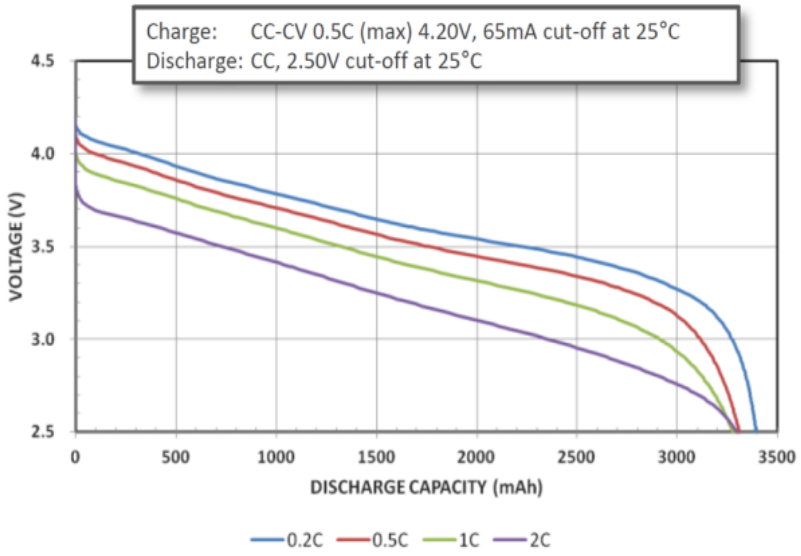
- Energy and capacity at RT (Clause 7.1)
- Energy and capacity at different temperature and discharge rates (Clause 7.2)
- Power and internal resistance (Clause 7.3)
- No load SOC loss (Clause 7.4)
- SOC loss at storage (Clause 7.5)
- Cranking power at low temperature (Clause 7.6)
- Cranking power at high temperature [a] (Clause 7.7)
- Energy efficiency [a] (Clause 7.8)
- Energy efficiency at fast charging [b] (Clause 7.9)
- Cycle life (Clause 7.10)

- Temperature
- DOD
- Roading condition
- Internal resistance

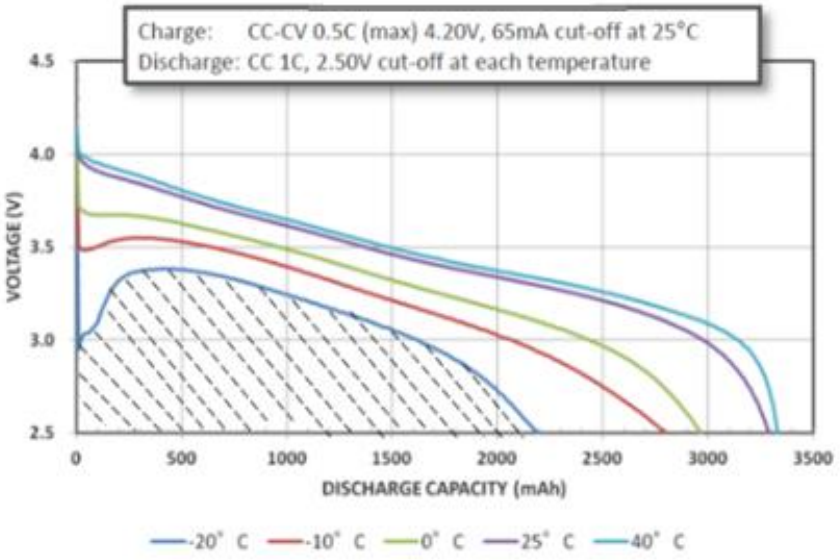
Test purpose
-battery indicators
-conditions led to battery performance degradation

- High-speed battery data collection
- Multi-dimensional analysis of battery data

Discharge Characteristics (by rate of discharge)



Discharge Characteristics (by temperature)



E.g. Integral algorithm of battery capacity

What challenges for EV battery testing ?

01 Higher voltage/power

- the difficulty of wiring
- the risk of electric shock

02 High-speed current Switching time

Traditional solution
- Source + Load

- **Automatic**
- **Safe**
- **Friendly UI**
- **High precision**

01 High-speed data collection /analysis

- Fast data acquisition
- Curves showing changes along with temperatures
- Battery attenuation
- Intuitive

ITECH solutions – overcome the test challenges

Test range - From battery cell to battery system

Hardware

IT6000C/IT6000B (3U 18kW)
Bidirectional/Regenerative power system

Fast-Seamless Switching

- ✓ Large-capacity buffer - high-speed sampling
- ✓ Fast switching between charge and discharge
- ✓ Regenerative, feedback efficiency up to 95%
- ✓ Output- **2250V**max **1.152MW**max
- ✓ Battery test & battery simulation

System

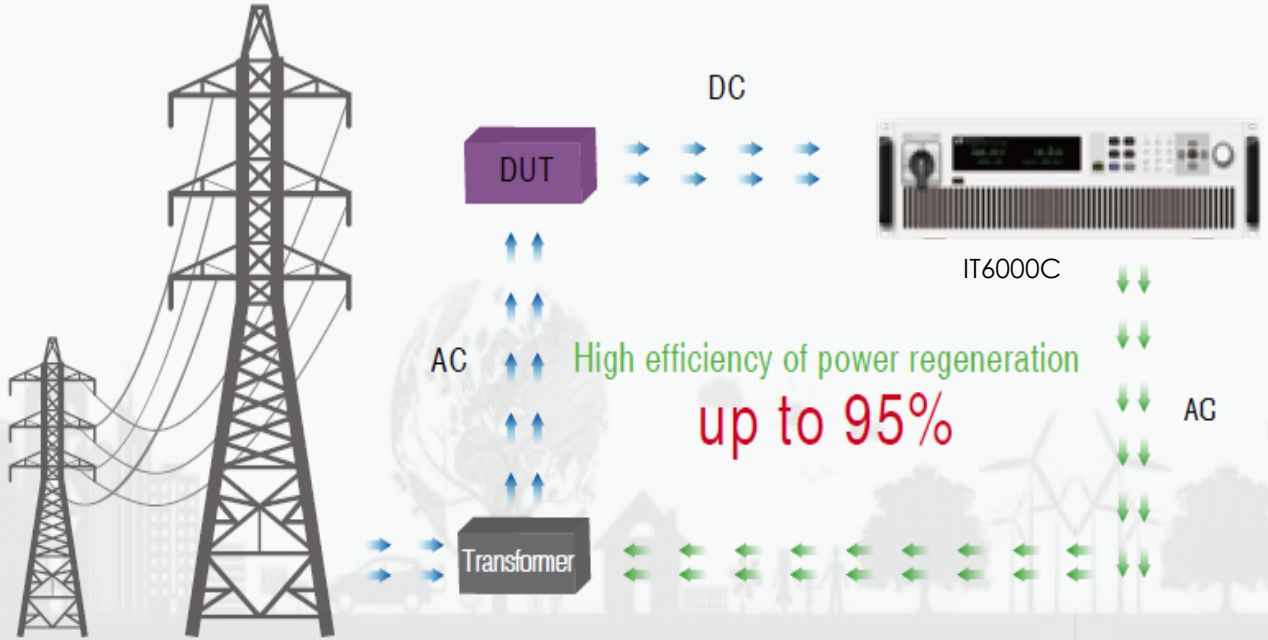
ITS5300 Battery Test System

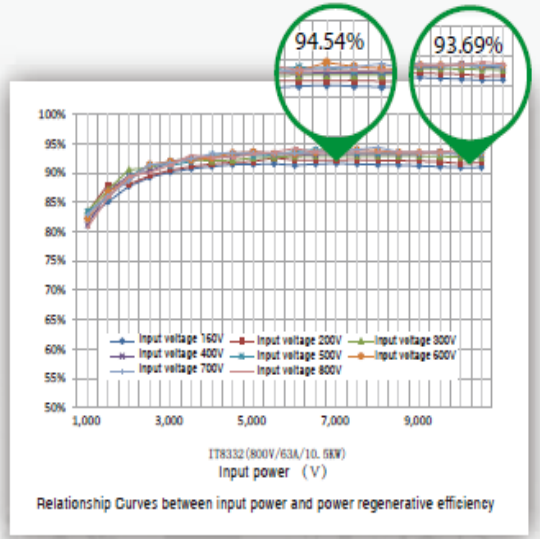
95%
Regenerative

- ✓ Sampling rate up to **1ms**
- ✓ Rich steps and roading condition simulation
- ✓ Complete report and statistical analysis
- ✓ Flexible switching - multi-channel / parallel

ITECH solutions – overcome the test challenges

- High power density
- Bidirectional
- Power regenerative - 95%





ITECH solutions – overcome the test challenges

Seamless

Current switching
-83A to +83A
<2ms (1.86ms)
=**72A/ms**

Battery charging / discharging
IT6018C-500-90

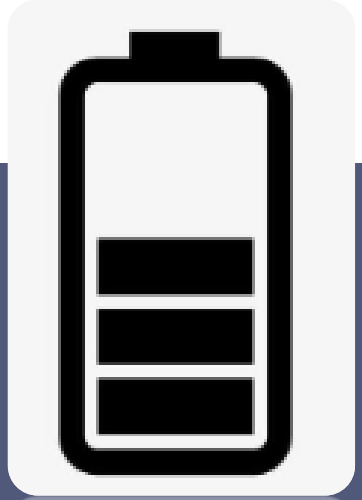
ITECH solutions – overcome the test challenges

- Unique parallel connection technology
- No calibration needed

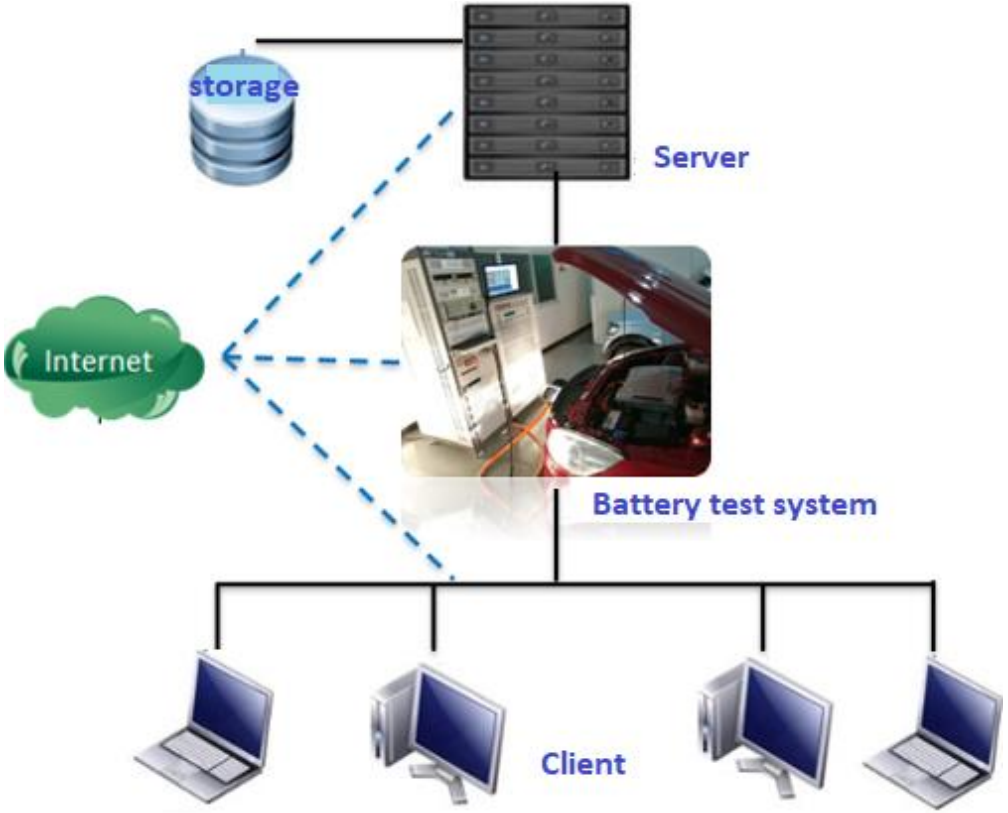
90kW	90kW	90kW	90kW
180kW		180kW	
270kW			90kW
360kW			

- ✓ Battery charge/discharge test
- ✓ Battery simulation

Battery Testing



ITS5300 Battery charging/discharging test



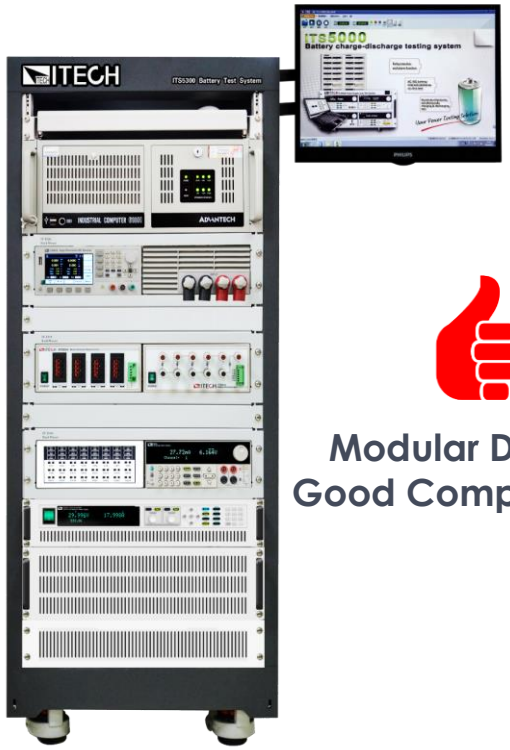
Highlights

- The battery test system can be controlled remotely within LAN
- The data is uploaded to server in real time, so it's safe and reliable
- Previous test data can be queried and accessed on any computer, good for production line

ITS5300 Battery charging/discharging test

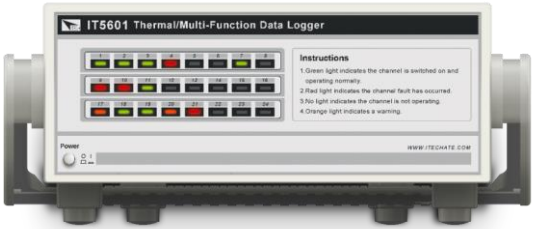
- ✓ Flexible modular design
- ✓ Well matched with temperature and humidity cabinet /temperature logger/ACIR tester

Temperature and humidity cabinet



Modular Design
Good Compatibility

Online ACIR tester: IT5102
(max. 16 channels)
Offline ACIR tester: IT5101

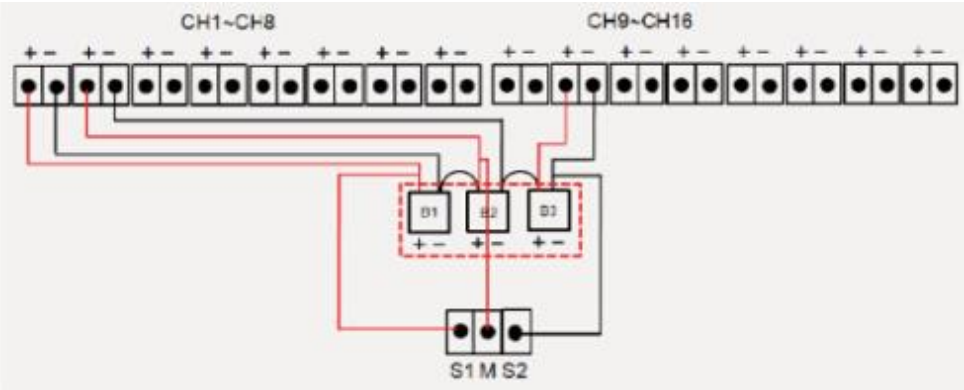


IT5601 Temperature logger
(max. 24 channels)

Advanced Online ACIR Tester

Different from the offline ACIR tester, the online ACIR testers allows monitoring of the voltage and internal resistance of the cells that inside the battery module while it is being charged and discharged.

Like in this example, battery module consists of three cells,B1,B2,B3. IT5102 can monitor the voltage and ACIR of each cell.

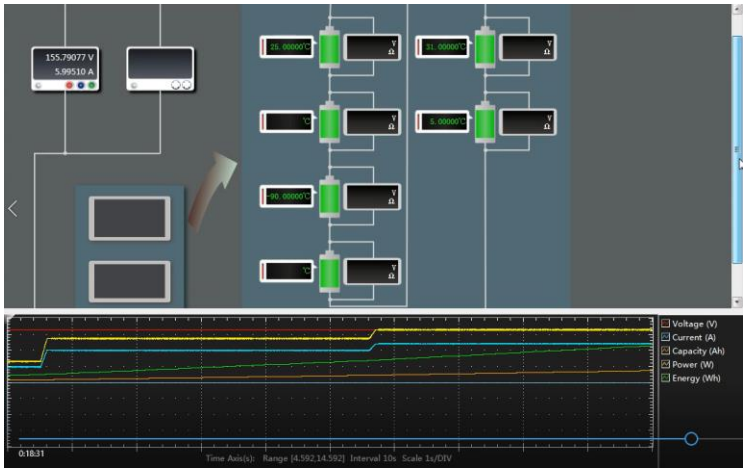


Friendly UI – fast configuration

Rich steps

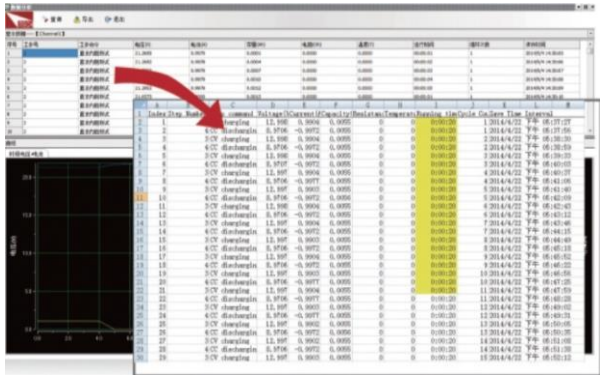
- CC Charge
- CV Charge
- CP Charge
- Driving Cycle Simulation
- CC Discharge
- CV Discharge
- Wait
- Delay
- DCIR Test
- CR Discharge
- CC-CV Charge
- CP Discharge
- CC-CV Discharge
- Reset
- IO Control
- High-low Temperature Chamber
- Cooling Control
- Auxilliary Power Supply Sett
- NormalChargeTest
- Loop
- ACIR Test
- CP-CV Discharge
- CAN Message Control

Real time monitor



Zoom in/out
Easy to check

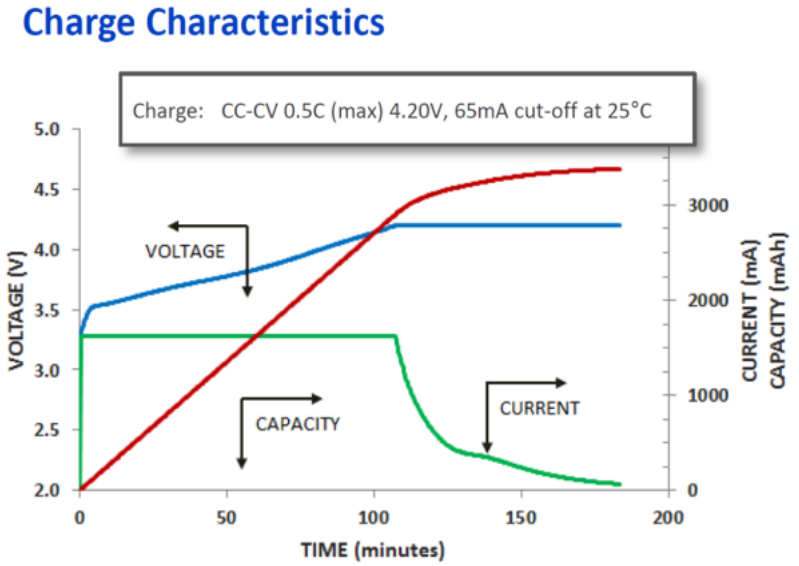
Data query/statistics



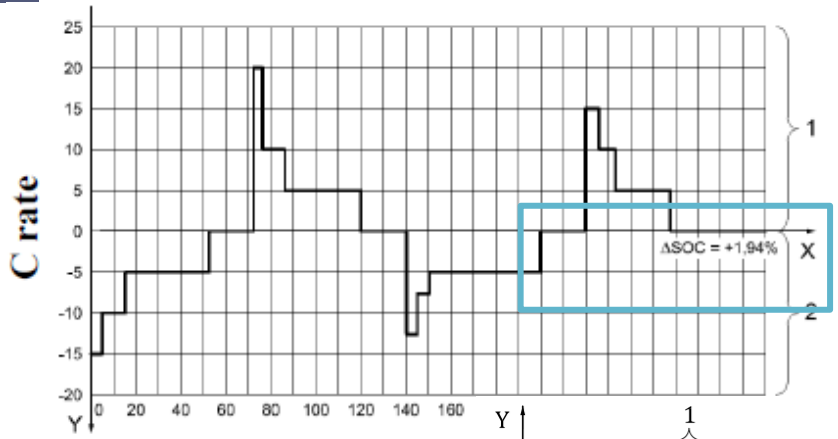
Fast analysis

Flexible combination of steps -comprehensive verification of battery performance

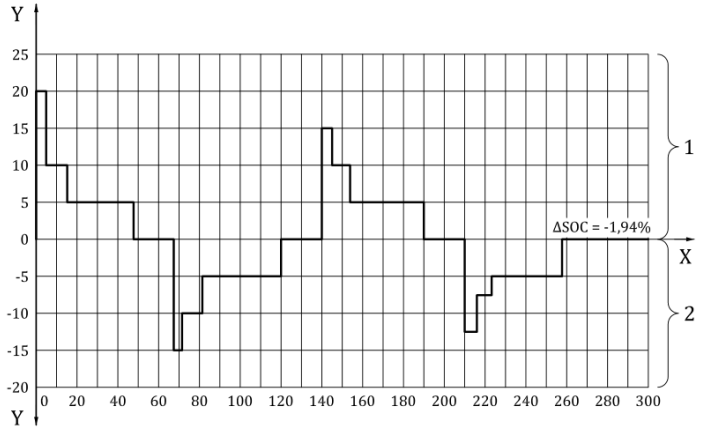
1 Battery capacity/energy test*
2 Battery life test (Static and Dynamic)*
3 SOC verification
4 Over-charge and over-discharge rate endurance test
5 Charging / discharging efficiency test
6 Driving working condition simulation *
7 Battery temperature characteristic test
8 Hybrid Pulse Power Characterization Test (HPPC test)*
9 BMS interaction function*
10 MES system communication



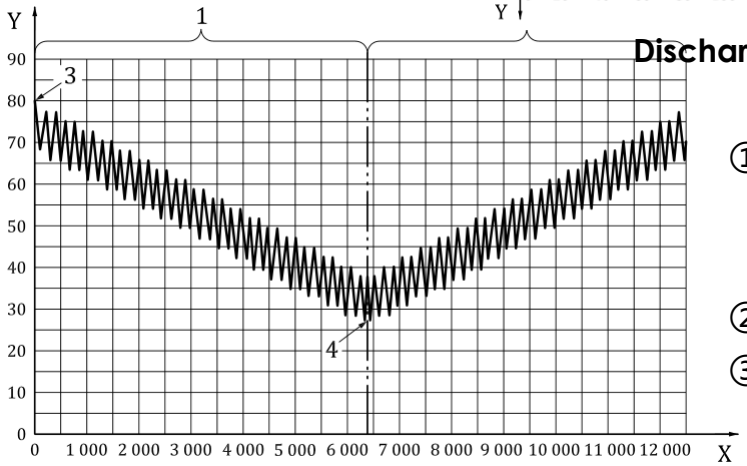
Application 1-Battery cycle life test under dynamic conditions



Charge-rich steps



Discharge-rich steps

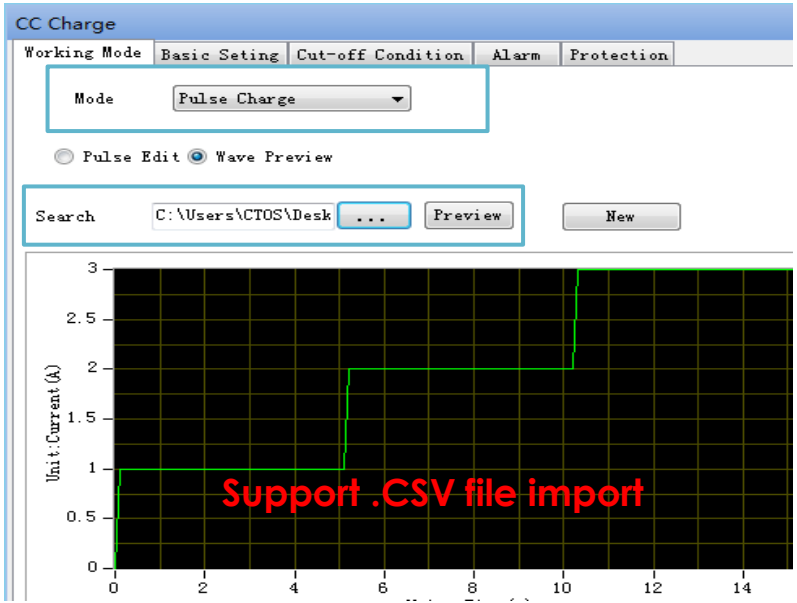


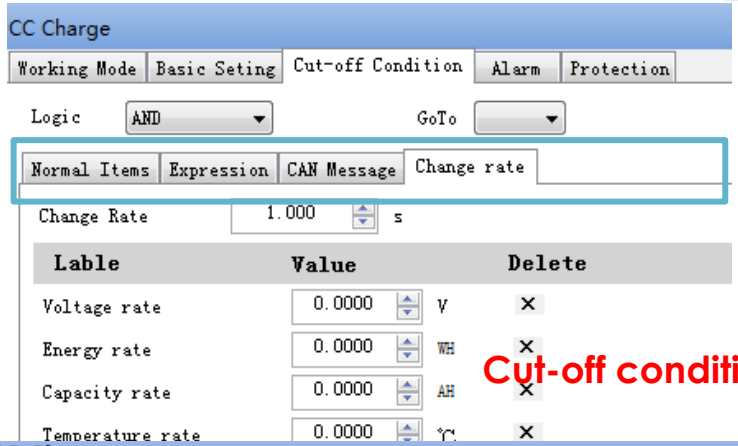
① Repeat two different curves and make SOC changing between 80%-30%.

② 22hrs/day testing, stop for 2hrs

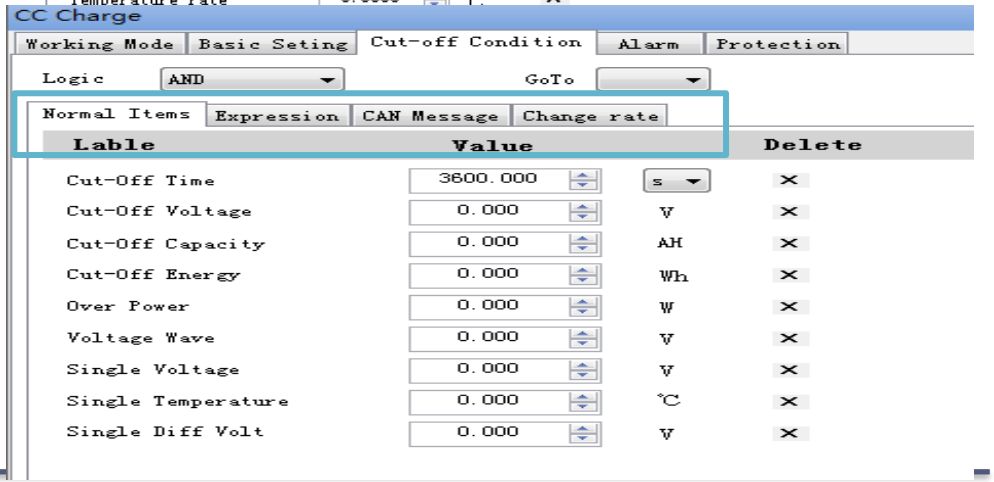
③ Check battery statues/week

Cut-off condition – Reliable charging and discharging





Cut-off condition setting

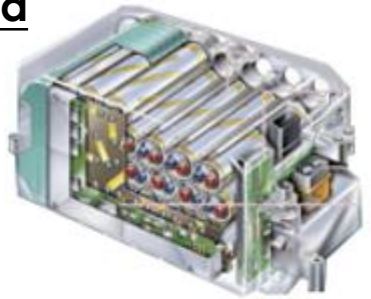


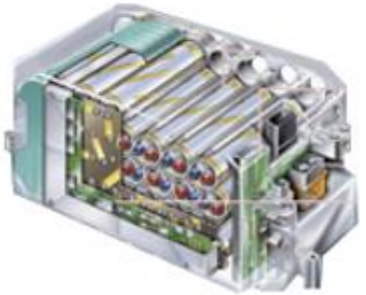
Fast sampling rate ensures high precision data

Accumulated battery capacity - Integral method

Conventional test system

Data transmission speed: 100ms





Make the capacity integral calculation in local, sample rate is 1ms. Then transfer the result to PC.

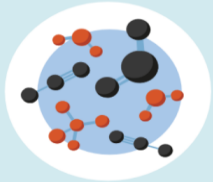
Driving working condition simulation

Simulate vehicle real driving data
Purpose: measure fuel consumption and CO2 emissions from EV

LABORATORY TESTS FOR PASSENGER CARS MEASURE:

FUEL CONSUMPTION

CO2 EMISSIONS
which are directly related to fuel consumption



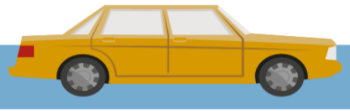
POLLUTANT EMISSIONS

ENERGY CONSUMPTION VALUES OF ALTERNATIVE POWERTRAINS
as well as the range of electric vehicles

NEDC

New European Driving Cycle

- Designed in the **1980s**
- Based on **theoretical driving**
- Has become **outdated**



OLD TEST → **NEW TEST**

WLTP

Worldwide Harmonised Light Vehicle Test Procedure

- Coming into force in **2017**
- Based on **real-driving data**
- Better matches **on-road performance**

Driving working condition simulation

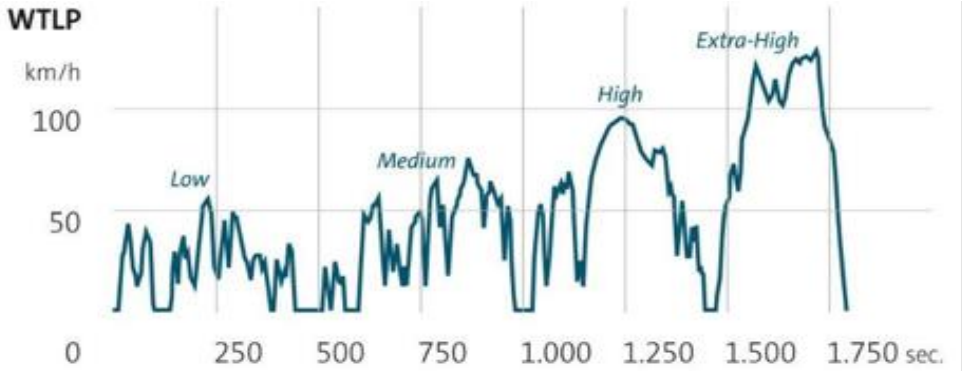
Challenges

1、Irregular changes

2、Simulation points need up to hundreds of thousands

3、Ultra-fast +I /-I rising/falling speed

4、Seamless +I and –I switching

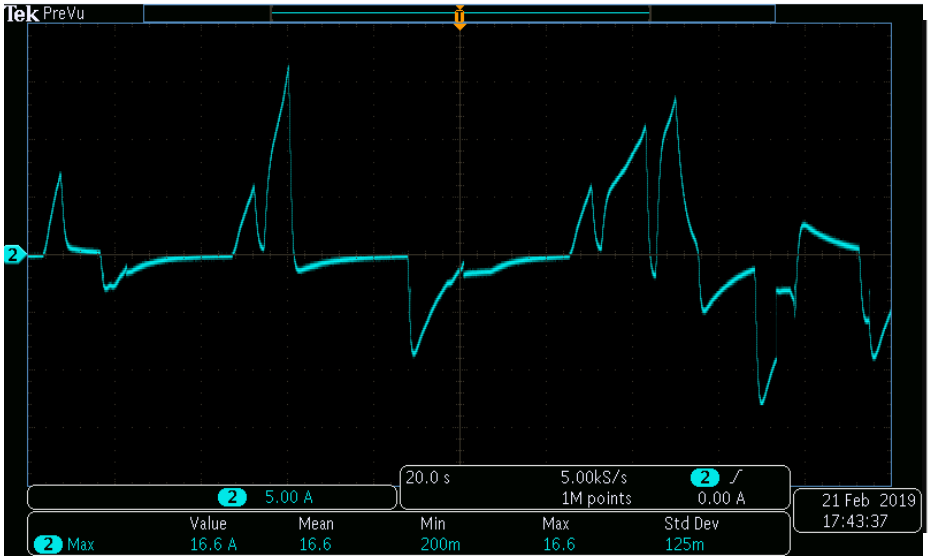


**All above requests makes the simulation complicated and extremely fast.

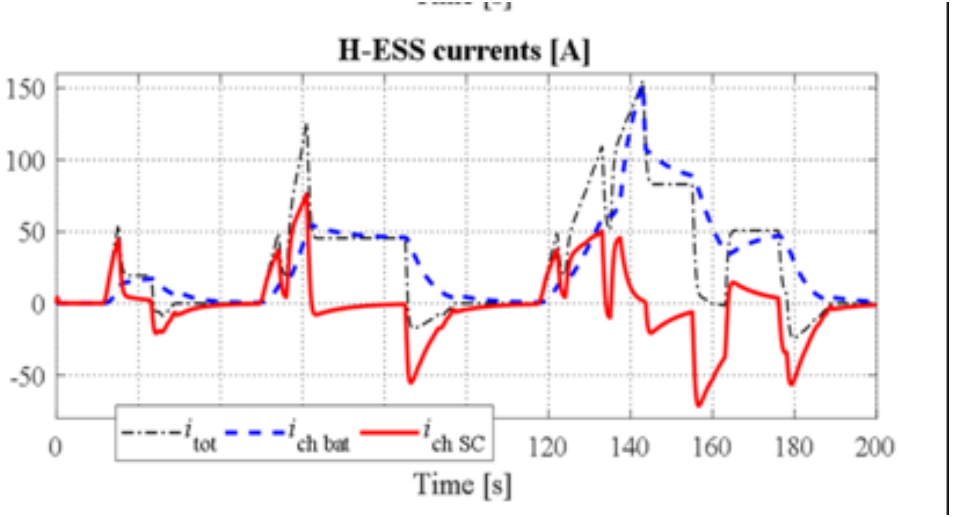
Driving working condition simulation

ITECH

ITS5300 simulation curve



Test requirement



Real-time monitoring of battery cells

CAN communication with BMS

charging

Discharging

Battery

BMS send battery status to ITS5300

A Save data reported by BMS

Use BMS reported data as cut-off condition B

C The battery cell voltage difference exceeds the limit -stop charging and discharging

Compatible with multiple BMS protocol

Lo scopo del messaggio MODULE_GLOBAL_VOLTAGE è di informare riguardo alla situazione generale della carica del singolo modulo.

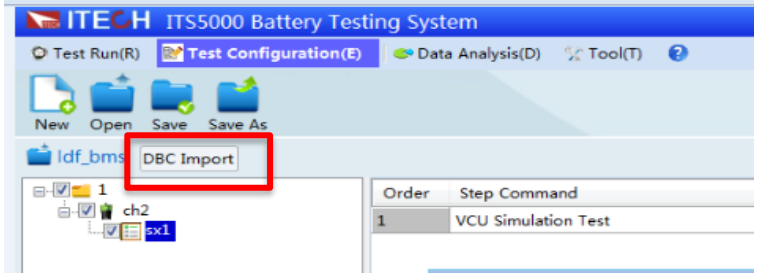
Direzione	BSU ==> ME
Nome	**MODULE_GLOBAL_VOLTAGE**
Descrizione	Informazioni relative ai livelli di tensione del singolo modulo
CAN-ID (hex)	**0x520 + <Module ID>**
Lunghezza	8 byte
Periodo invio	1000 ms

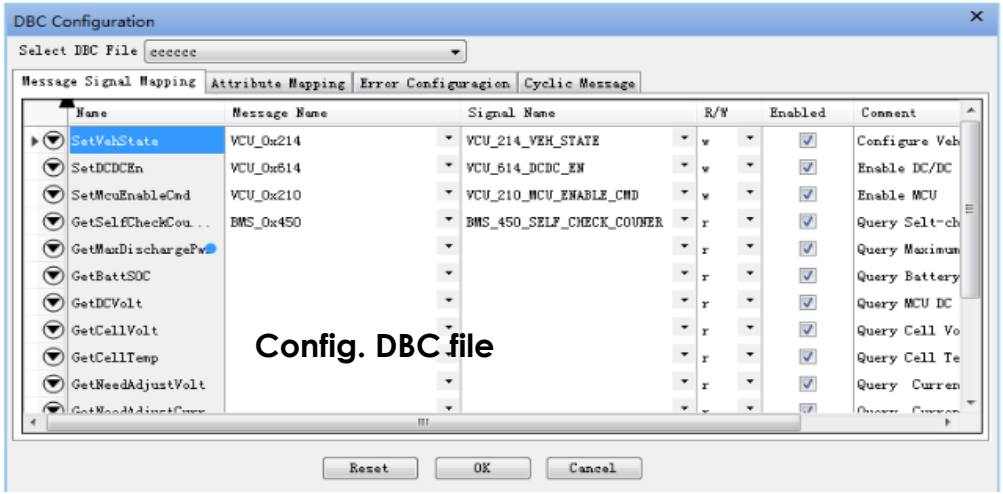
Nome del Campo	Bit start	Lunghezza (bit)	Range	Range di validità	Data Type	Fattore	Unità	Note
Module ID	0	8	0..255	1..13	U8	-	-	ID del modulo
Max Cell Voltage	8	13	0-8191	0-4300	X16	1	mV	Valore di tensione più alto
Max Cell Voltage N	21	5	0-511	1-9	X8	-	-	Numero cella a tensione più alta
Min Cell Voltage	26	13	0-8191	0-4300	X16	1	mV	Valore di tensione più basso
Min Cell Voltage N	39	5	0-511	1-9	X8	-	-	Numero cella a tensione più bassa
Total Voltage	44	17	0-131071	0-38700	X17	1	mV	Tensione globale del modulo

Tabella 4 – Messaggio MODULE_GLOBAL_VOLTAGE

```
BO_ 2147483924 BMS_0x114: 8 Vector__XXX
 SG_ BMS_114_CELL8_RES : 63|8@0- (0.1,0) [0|0] "" Vector__XXX
 SG_ BMS_114_CELL7_RES : 55|8@0- (0.1,0) [0|0] "" Vector__XXX
 SG_ BMS_114_CELL6_RES : 47|8@0- (0.1,0) [0|0] "" Vector__XXX
 SG_ BMS_114_CELL5_RES : 39|8@0- (0.1,0) [0|0] "" Vector__XXX
 SG_ BMS_114_CELL4_RES : 31|8@0- (0.1,0) [0|0] "" Vector__XXX
 SG_ BMS_114_CELL3_RES : 23|8@0- (0.1,0) [0|0] "" Vector__XXX
 SG_ BMS_114_CELL2_RES : 15|8@0- (0.1,0) [0|0] "" Vector__XXX
 SG_ BMS_114_CELL1_RES : 7|8@0- (0.1,0) [0|0] "" Vector__XXX
```

.dbc file demo





Config. DBC file

Challenges that most engineers care about

Users of EV battery usually want to know

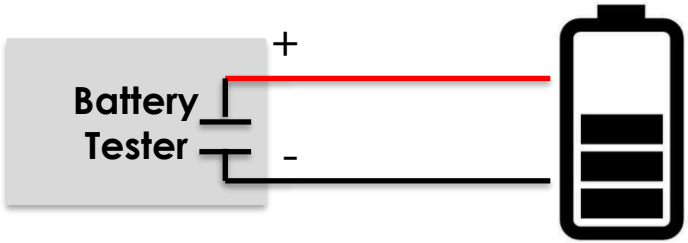
- How to deal with the sparks of the high-voltage and large-capacity EV batteries ?
- If the PC going down during operation, can we save the test data ?
- After the test is completed, will the data such as the attenuation rate of the battery be calculated ?

ITECH gives the answers

- **ITS5300 Battery Test System**
  - Complete solution for battery performance verification
  - Innovative technical approaches

Solution1： How to deal with the sparks ?

Why there are sparks

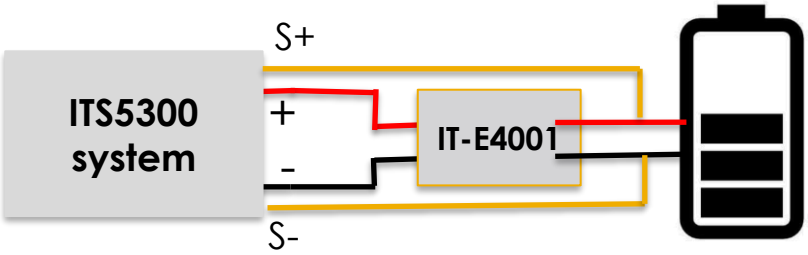


① There is a capacitor at the output port of the test instrument and its initial capacitor voltage is 0V.

② The battery is on – it charges the capacitor – the capacitor is in short circuit state

③ A large charging current creates sparks at the moment it's connected

ITS5300 battery test system



Anti reverse connection and sparking module

IT-E4001- Anti reverse connection and sparking module

-physically separates the test instrument from the battery

-detects battery polarity and tell whether it's connected reversely

-measures the voltage of battery , charges the capacity of the battery tester and make it close to the voltage of the battery.

➢ So the battery and the battery test system can be safely connected.

Solution2: What can we do if it's abnormal in the battery cycle life test?

PC goes down

Does the system keep charging the battery and lead to overcharging?

Will it lose control when … ?

Power-off

Data saved ?

All steps needed to repeat again ?

Solution: Anti power down protection module

ITS5300 Battery Test System configured with IT-E4003 protection module

Solution2: What can we do if it's abnormal in the battery cycle life test?

IT-E4003 Anti-crash protection module - ensure the safe storage of test data

IPC

Battery test system

Battery

monitor

IT-E4003

monitor

Test program

Step1	CC-CV charging
Step2	Delay
Step3	CC discharging (Power-off during the test)
Step4	Cycle

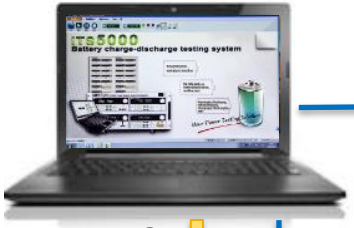
detect

IT-E4003 power for PC to make sure the test data saved in time

Record the error step, when power turns normal, continue test from Step3.

Solution2: What can we do if it's abnormal in the battery cycle life test?

IT-E4003 Anti-crash protection module - ensure the safe storage of test data



IPC

Battery test system

Battery

monitor

IT-E4003

monitor

Test program

Step1	CC-CV charging
Step2	Delay
Step3	CC discharging (IPC down and lost remote control)
Step4	Cycle

detect

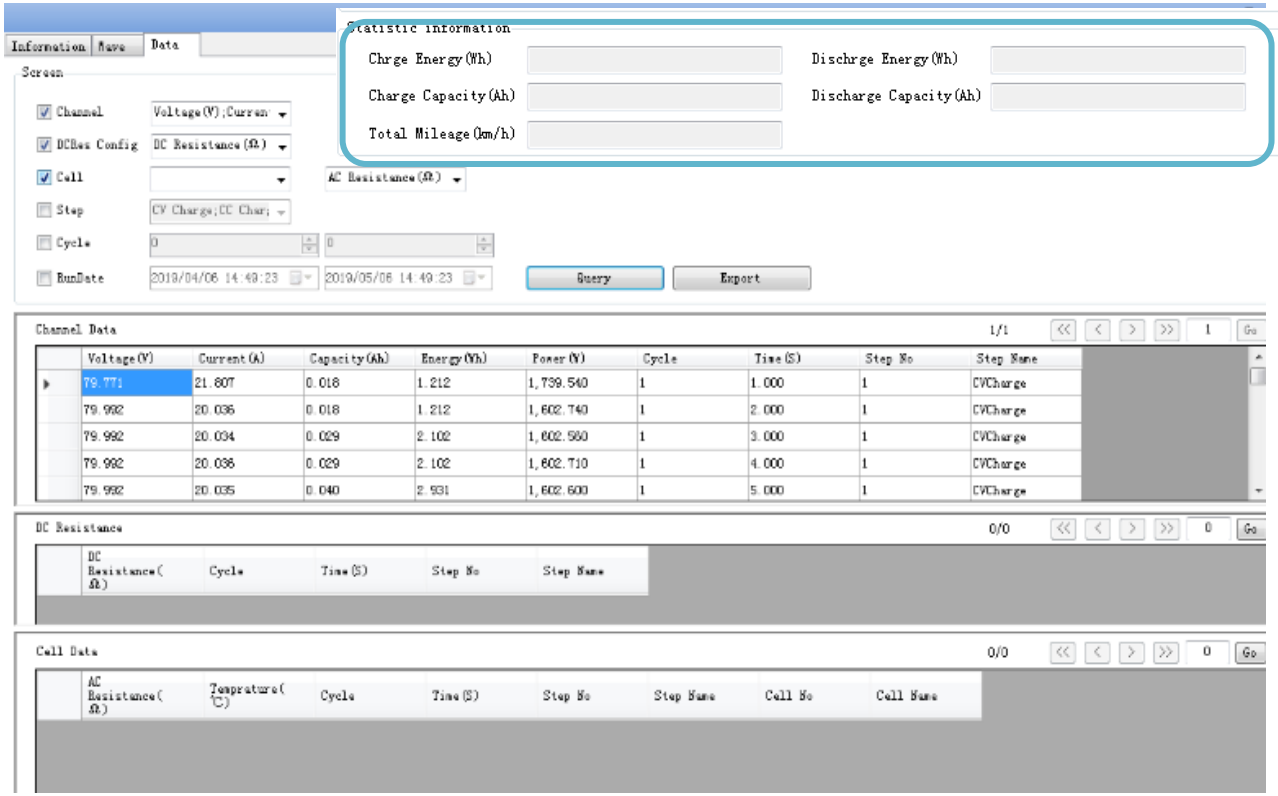
Turn off the hardware within 30s, stop the test process safely.

IT-E4003 restart the IPC and if starts successfully, ITS5300 will continue the test process from Step3 automatically.

Data query and statistics

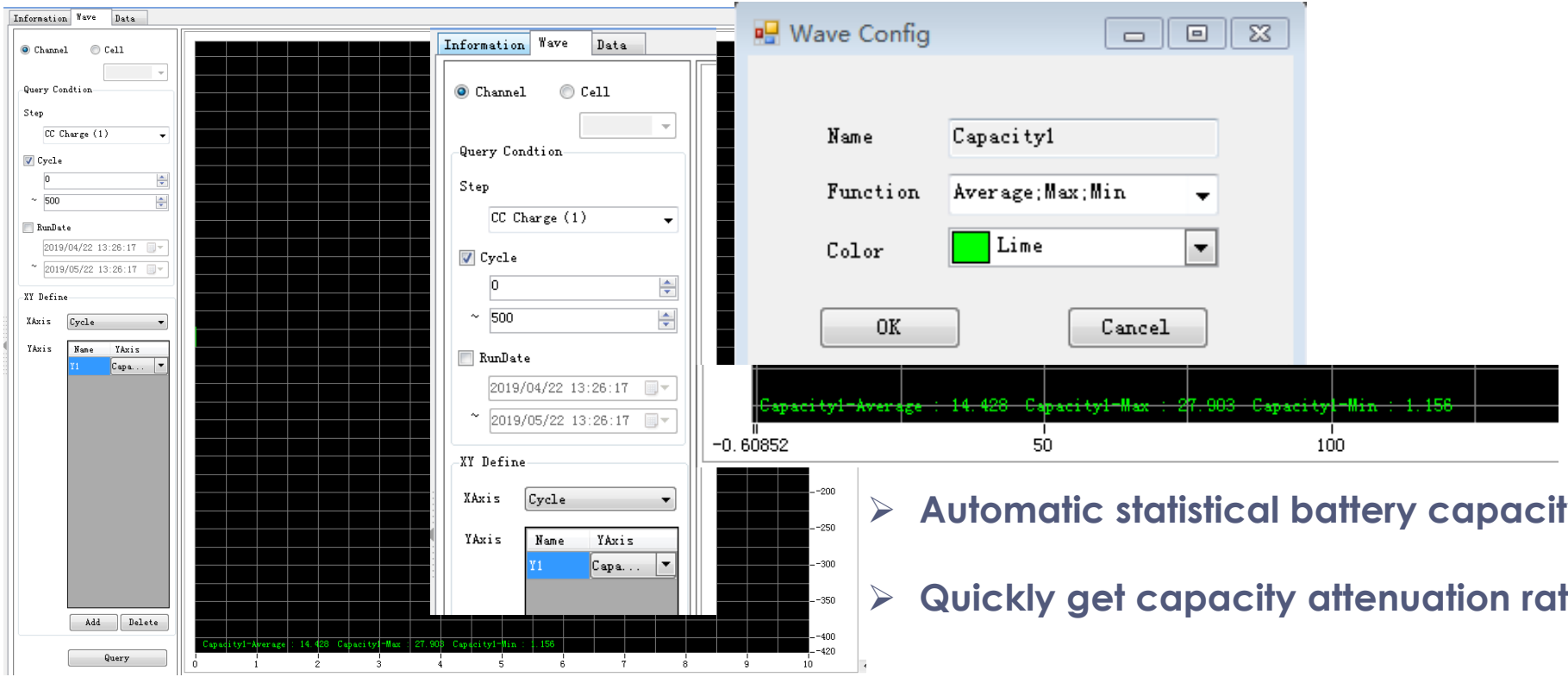
Statistics Query Conditions

1) Channel
2) Cell
3) Step
4) Cycle
5) Run Time



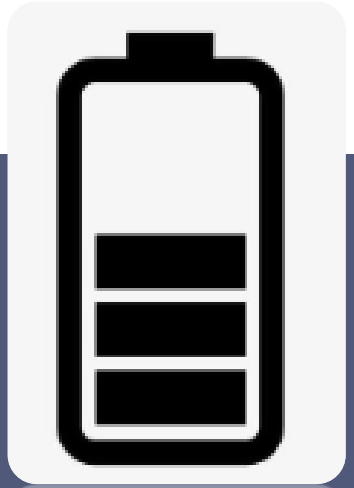
Solution3: How to quickly analyze battery performance ?

Battery capacity attenuation rate



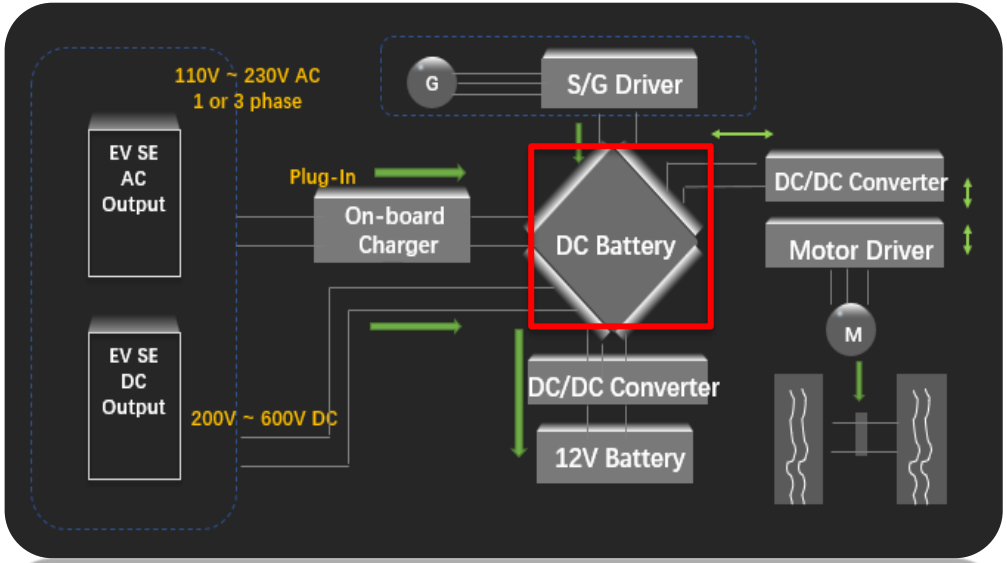
- Automatic statistical battery capacity
- Quickly get capacity attenuation rate

Battery Emulation



Battery simulator
-necessary for RD of EV powertrain and automotive electronic equipment

What kinds of battery emulator can meet the strict testing requirements?



01

Battery Emulator

EV powertrain

02

Gird simulator

Battery Emulator

DC charger (V2X)

03

Gird simulator

BOBC(V2X)

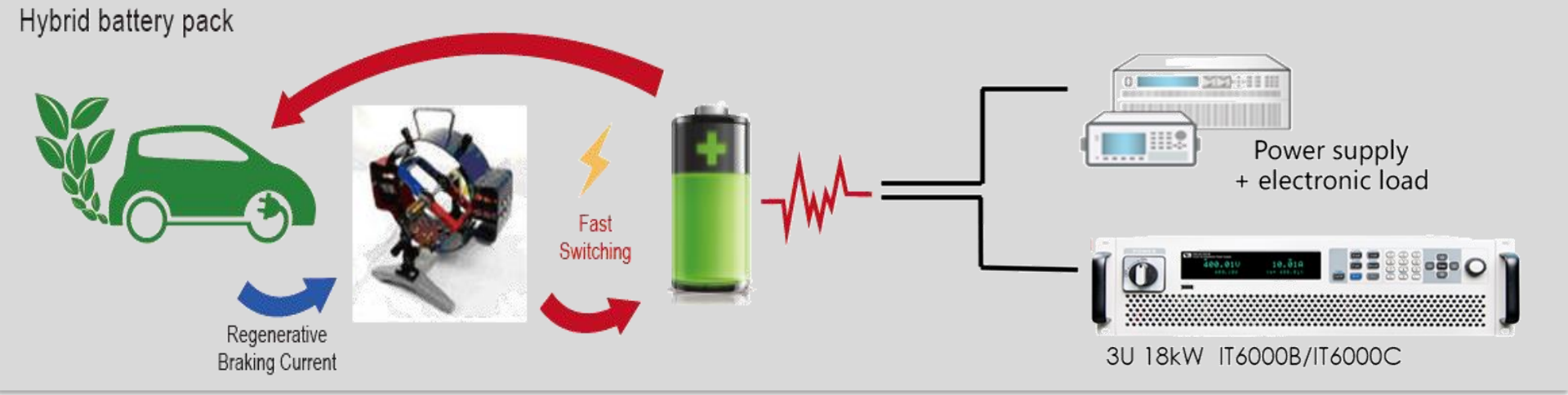
Battery Emulator

ITECH bidirectional solution VS Traditional source + load solution

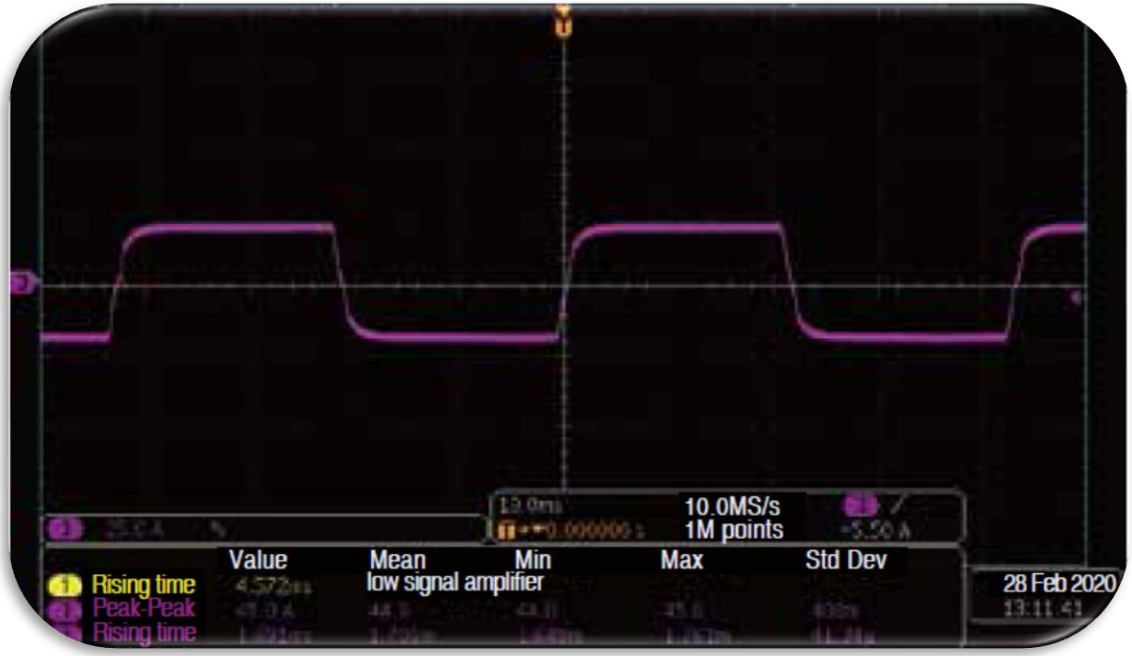
Source + load solution

1. Response time of a DC power supply -10 to 100 ms (too slow for EV powertrain test)
2. DC load to modulate power or provide a return path for back EMF - A lot of work on software and integration
3. The internal resistance of the battery is difficult to accurately simulated

Bidirectional DC power supply (IT6000B/IT6000C)
----Seamless switching between charge/discharge



ITECH bidirectional solution
- Seamless switching between source and sink



Waveform screenshot – test using IT6000C bidirectional DC power supply

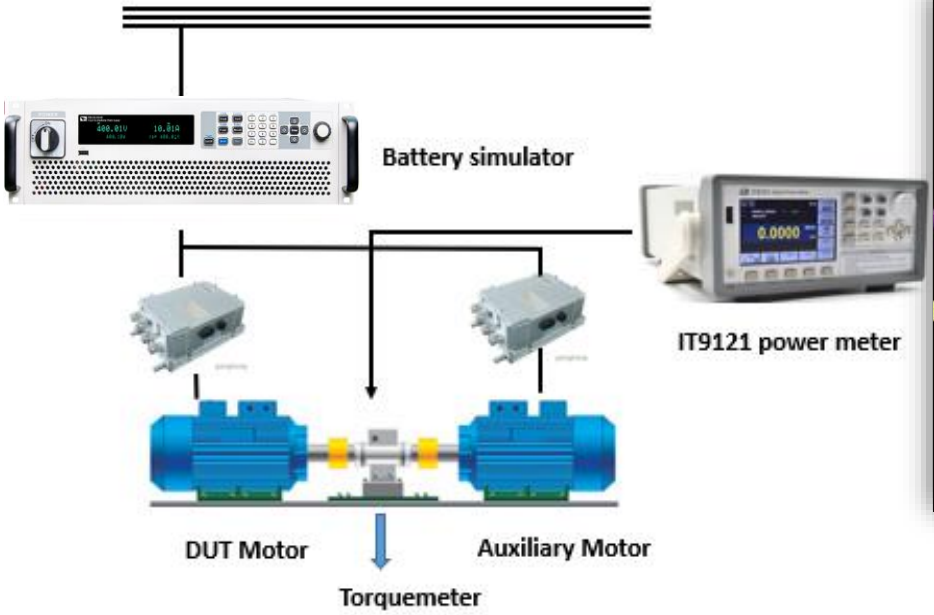
Typical application – Testing solution for motor drive

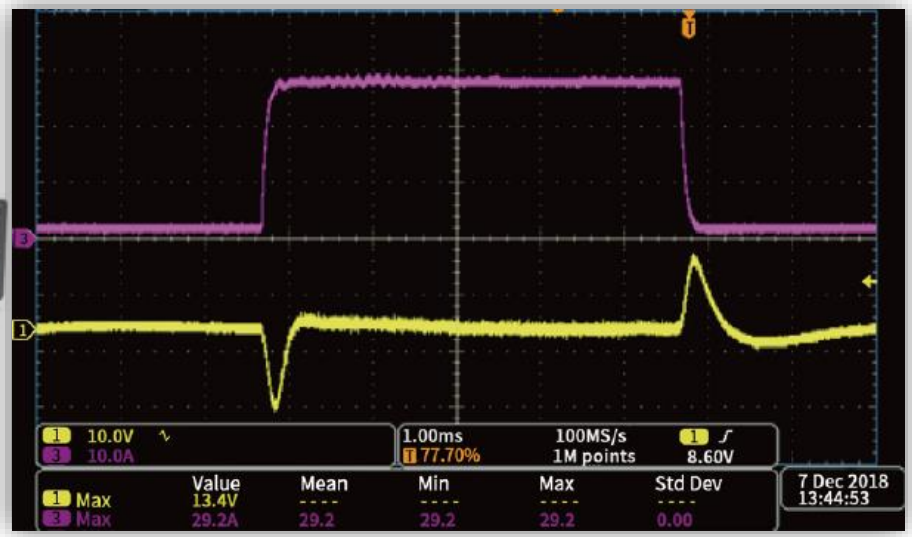
Short response (<2ms)

When the motor speed fluctuates,

- The faster the dynamic response is, the faster the output voltage can return to stability
- Avoid triggering UVP

Advantage





IT6018C-1500-30

Dynamic response time <2ms

New challenge - battery characteristic simulation

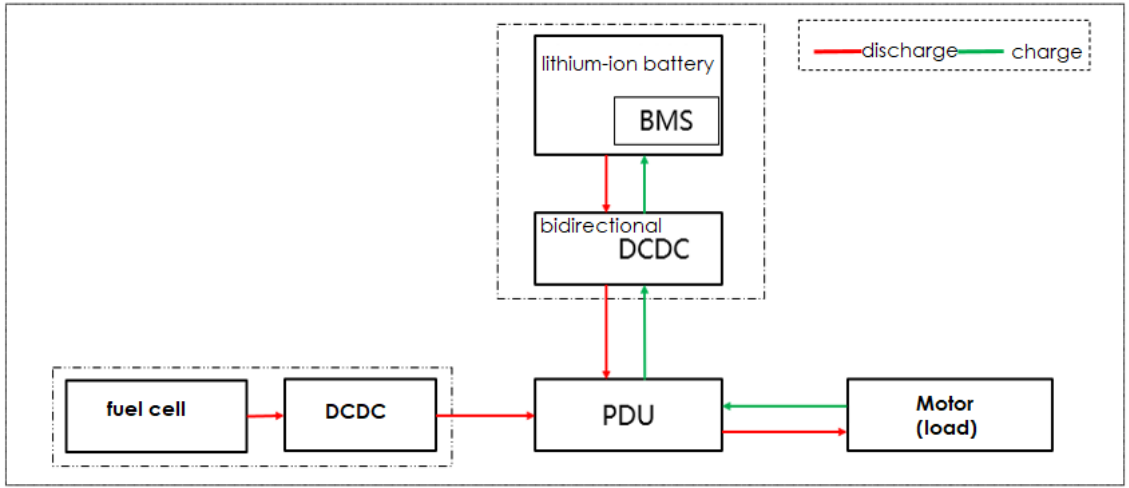
Verify the energy management strategy of the hybrid power system (fuel cell & lithium battery)

Test purpose

- Figure out the reasonable ratio between fuel cell and lithium-ion battery under roading condition
- Ensure the EV performance and extend the battery life as well

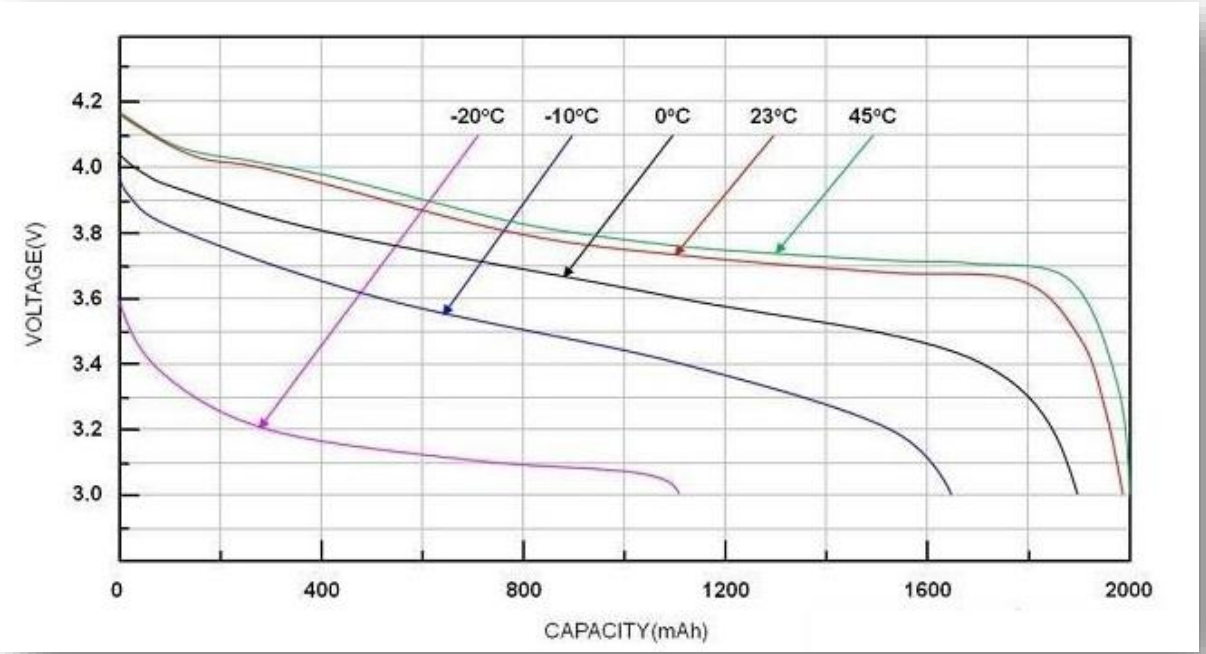
Challenge

- Simulate characteristic curve of batteries
- Real-time report parameters - SOC, voltage, current and power



- Mode 1: Both lithium-ion battery and fuel cell power the motor
- Mode 2: Fuel cell not only powers the motor but also charges the lithium-ion battery (low SOC)
- Mode 3: The braking energy of the motor is fed back to the lithium-ion battery

New challenge - battery characteristic simulation



Challenges

- There are many I-V curves

  -Temperature change

  -Battery types change

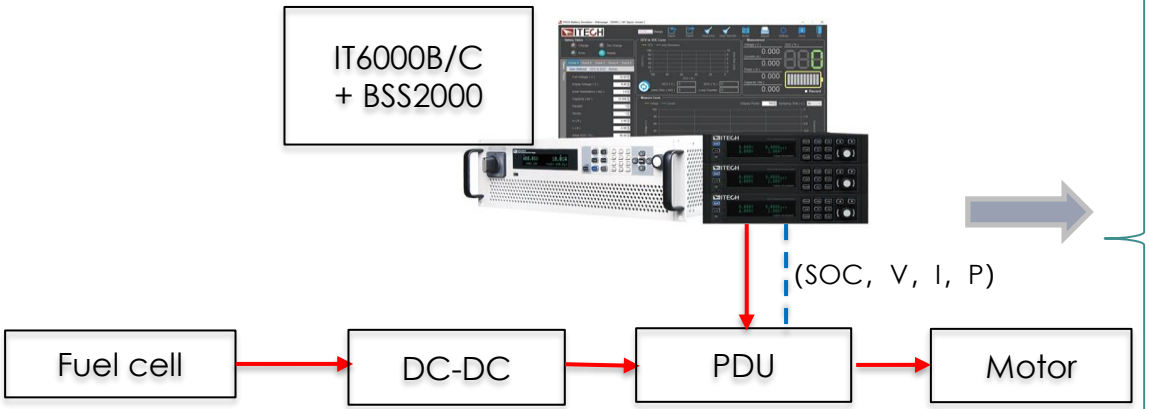
…

- Engineers have little knowledge of battery characteristics

New challenge - battery characteristic simulation

ITECH test solution

- Bidirectional & regenerative DC power supply + battery simulation software



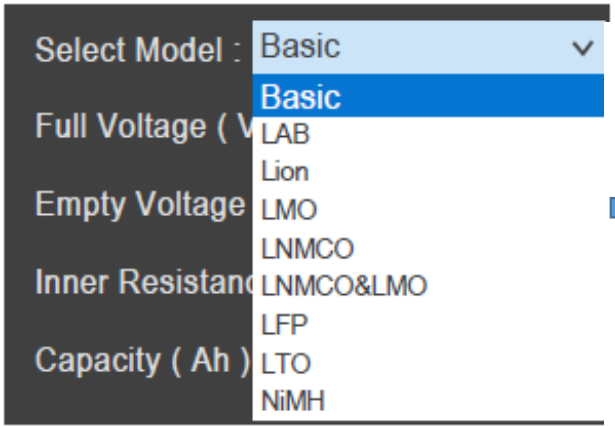
- Built-in battery characteristic curve
- Import V-C curve
- Mathematical modeling
- Import .mat file

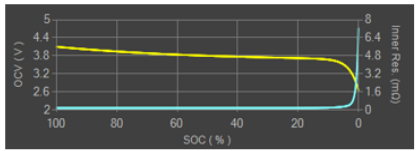
New challenge - battery characteristic simulation

8 built-in battery characteristic curves

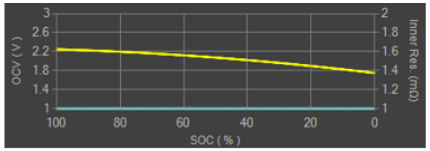
Friendly to users

- who don't know much about the batteries, like EV manufacturers
- who wants to make the test easier by recalling the built-in curves directly



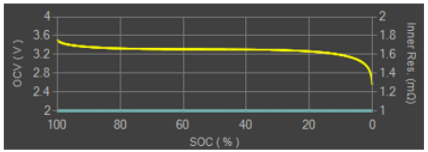


Lithium-ion battery

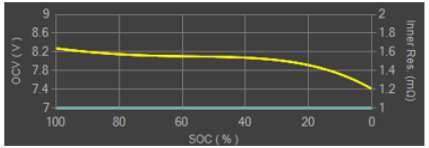


Lead-acid battery

.....



LFP

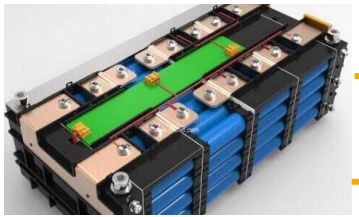


NiMH battery

New challenge - battery characteristic simulation

Based on the measured battery curve data, import the parameters into the software for simulation

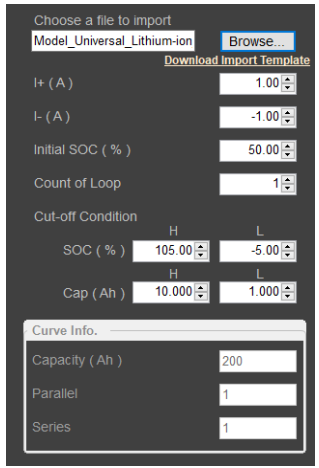
- Users can get the real battery charge and discharge data through the battery test system (OCV,SOC)
- Import the measured battery characteristic curve data into the battery simulation software for reproduction



ITS5300 battery test system

A	B	C
Model	IT6018C-1500-30	
File Type	Battery emulator	
Sub Type	Curve	
Curve Poin	1001	
Capacity	200	
Parallel	1	
Series	1	
SOC	VOC	R
0	2.654	7.25179
0.1	2.689676	6.28948
0.2	2.724133	5.463998
0.3	2.757411	4.755715
0.4	2.789552	4.147823
0.5	2.820595	3.625931
0.6	2.850577	3.177712
0.7	2.879535	2.792612
0.8	2.907504	2.461595
0.9	2.934519	2.176919
1	2.960611	1.931957
1.1	2.985813	1.721034

Measured data



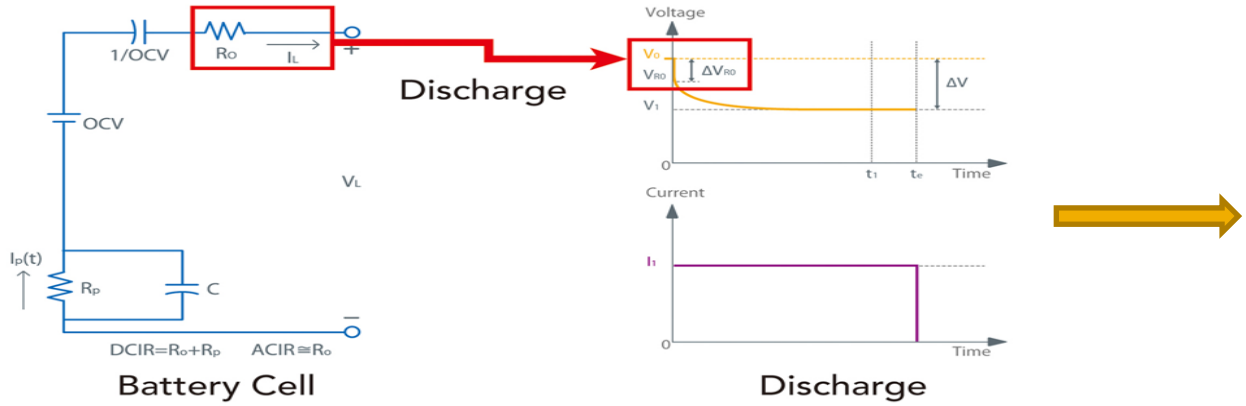
Data import

New challenge - battery characteristic simulation

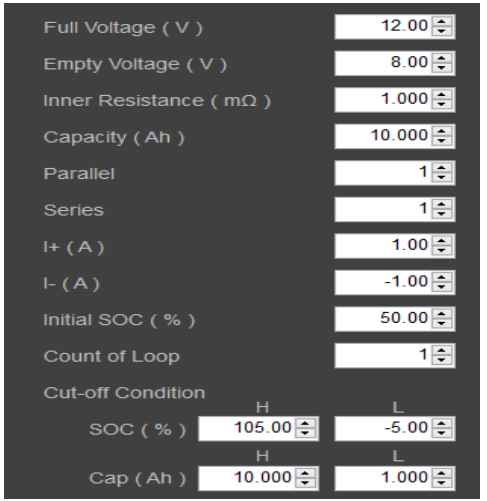
Simple parameter setting, fast simulation of battery characteristic curve (Basic mode)

- The battery software abstracts the battery into a standard mathematical model. Users only need to set the key parameters, and the software can automatically generate the corresponding curve according to the internal algorith
- Parameters： full voltage, empty voltage, number of series and parallel sections, internal resistance, rated capacity

* Suitable for battery curve simulation after different ambient temperature and internal resistance changes



Basic mathematical model of battery

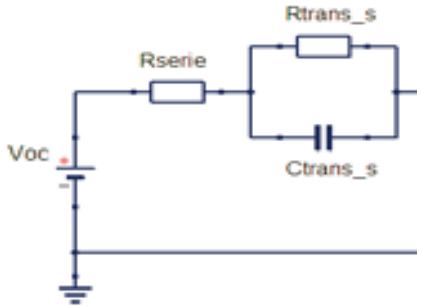


New challenge - battery characteristic simulation

.mat file import (BSS2000 Pro/BSS2000M)

Application:

- Advanced battery simulation requirements
- rebuild the mathematical model of the battery by Matlab tool
- Simulate the characteristic curves of new batteries / conventional batteries

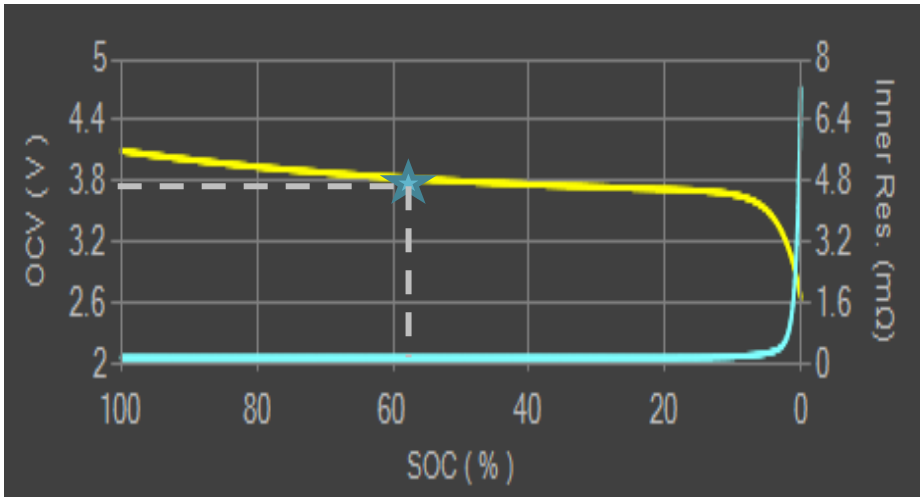


rebuild the mathematical model of the battery by Matlab tool

Generate .mat file

Import .mat file into BSS2000 Pro / BSS2000M

New challenge - battery characteristic simulation

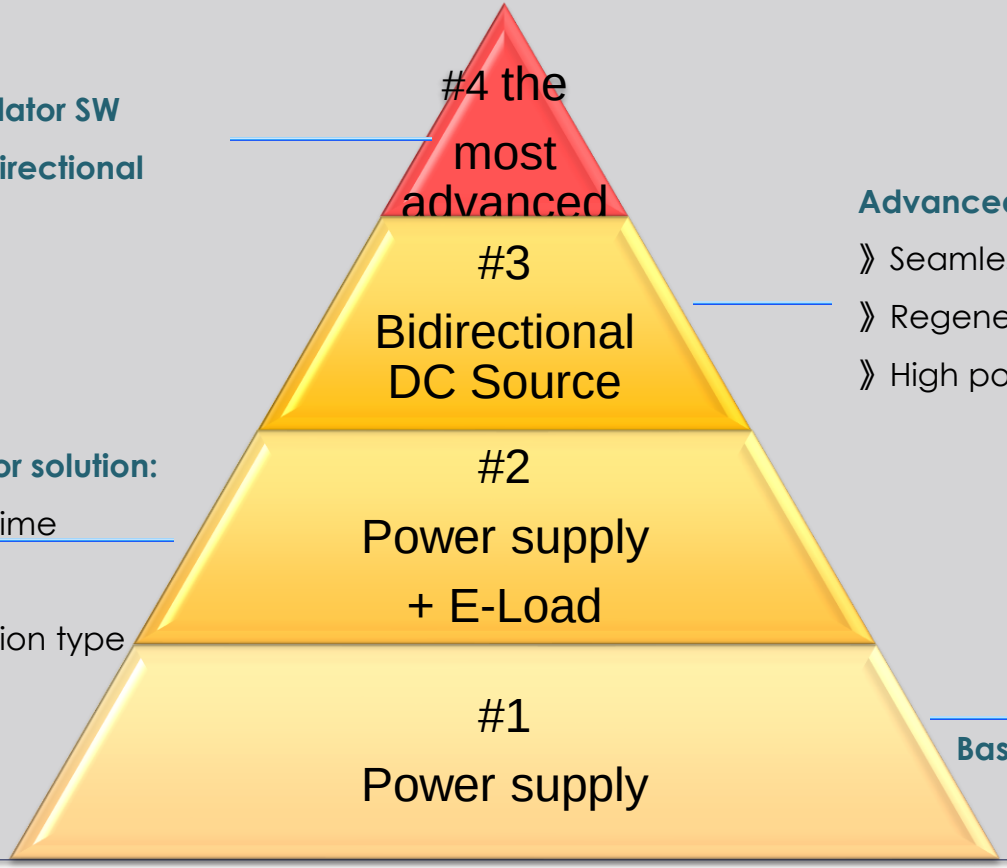


- arbitrarily specify the initial capacity of the battery between 0 and 100%
- SOC is 100% in the state of full charge.

- Easy to study the start-up characteristics of the DUT
- No need to use real battery for test

New challenge - battery characteristic simulation

ITECH battery simulator SW combined with Bidirectional DC power supply



Advanced battery simulator solution:

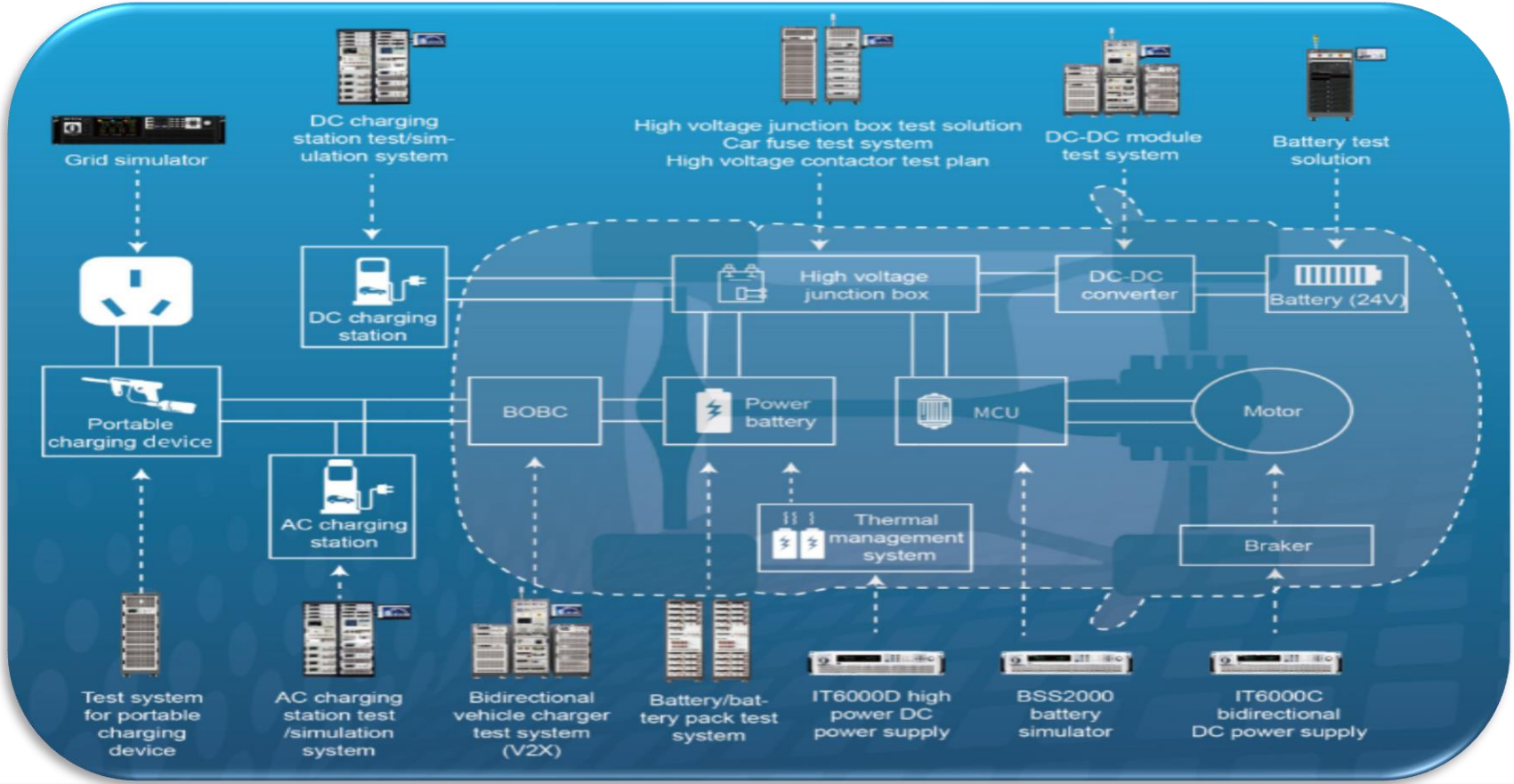
- 》 Seamless current switching
- 》 Regenerative solutions
- 》 High power density

Traditional Battery simulator solution:

- 》 Slow current switching time
- 》 large equipment size
- 》 traditional heat dissipation type

Basic solution for simple test

Complete testing solutions for EV industry

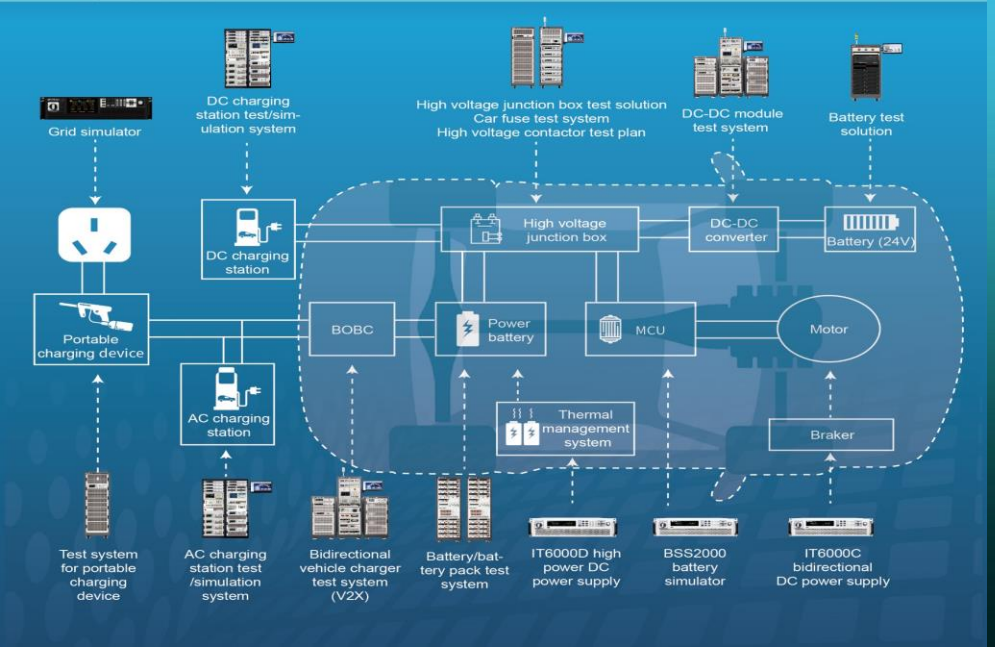


ITECH

ITECH Test Solution-EV

ITECH Web

ITECH Facebook

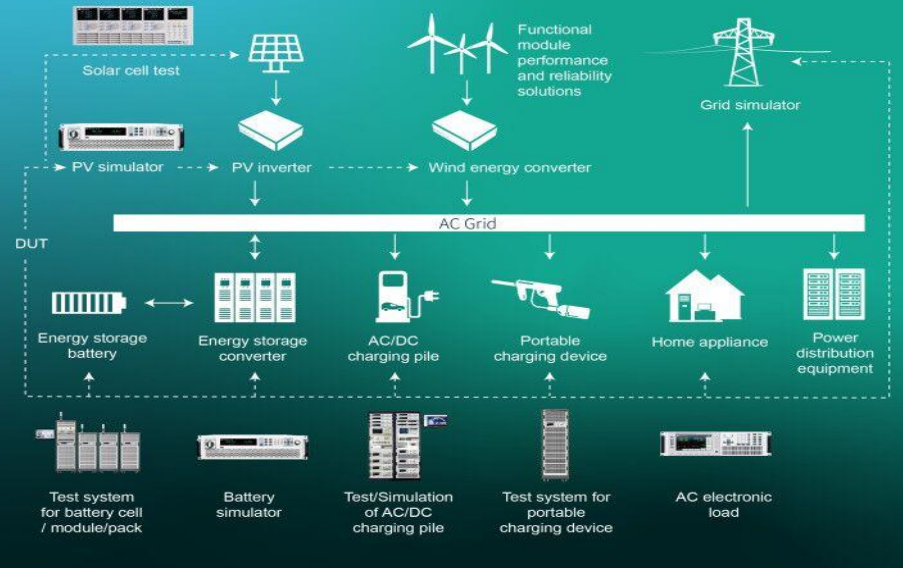


ITECH

ITECH Test Solution-Solar

ITECH Web

ITECH Facebook



ITECH

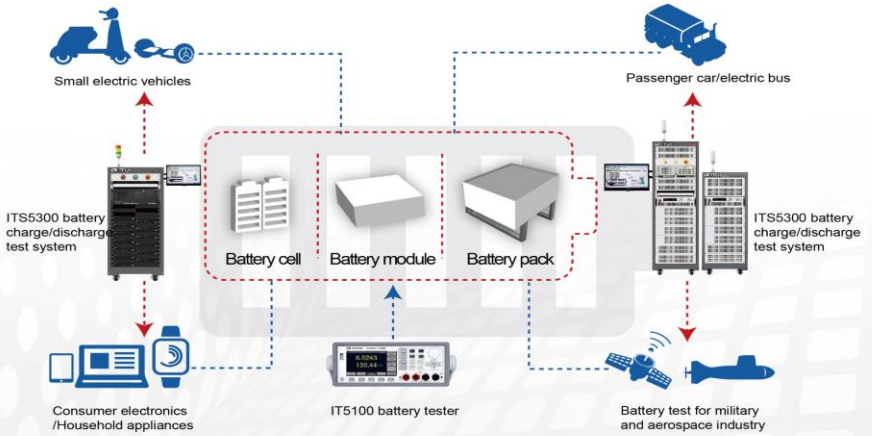
ITECH Test Solution- Battery

ITECH Web

ITECH Facebook

Regenerative test solution for battery cell/module/pack

- High regenerative efficiency, up to 95%
- High precision & fast sampling rate
- Road condition simulation
- Seamless current switching

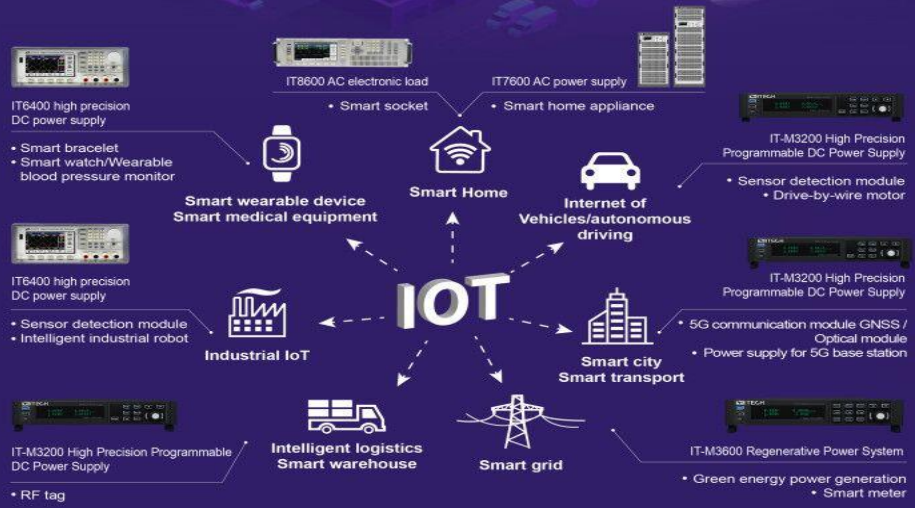


ITECH

ITECH Test Solution-IoT

ITECH Web

ITECH Facebook

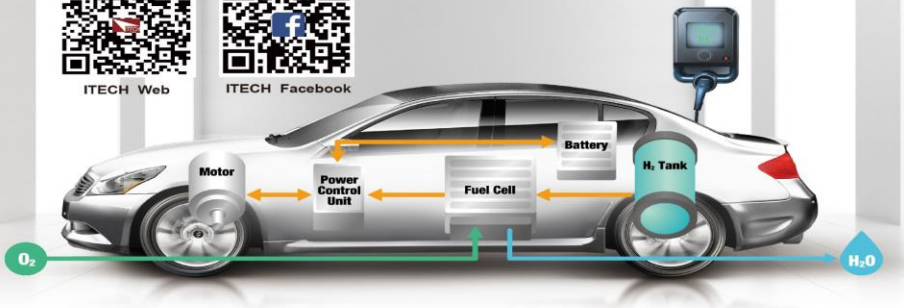


ITECH

ITECH Test Solution - Fuel Cell

ITECH Web

ITECH Facebook

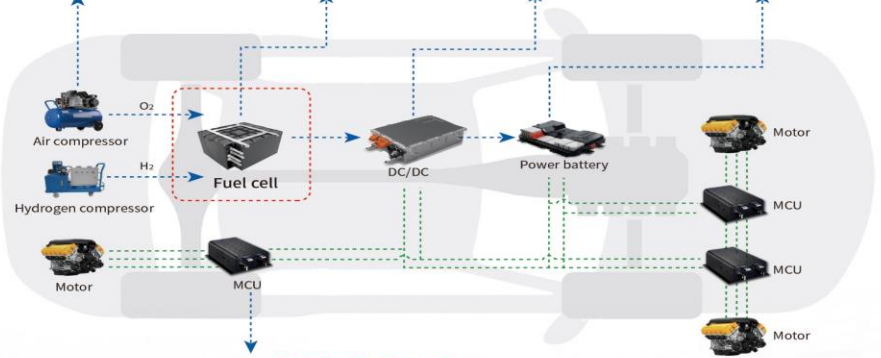


Air compressor test
IT6000D high power DC power supply

Test of fuel cell stack / fuel cell system
- IT8900A/E DC electronic load
- IT6000D high power DC power supply

DC-DC test
Fuel cell simulation FCS3000+IT6000B/C

Battery test
- ITS5300 battery charge/discharge test system
- IT6000B/C bidirectional DC power supply



Motor/motor drive test
Battery simulator BSS2000+IT6000B/C

ITECH

ITECH Test Solution-Power Supply

ITECH Web

ITECH Facebook

ITS9500 power supply test system

Power supply burning test system

AC-DC/DC-DC Power Module
AC-DC/DC-DC Bidirectional Power Module
Single Channel/Multiple-Channel Power Module
PCS/PV inverter

Battery simulator
PV simulator

AC programmable power supply
AC/DC electronic load

THANK YOU

ITECH

Thurlby Thandar Instrument Distribution
Glebe Road, Huntingdon, PE29 7DR, UK
+44 (0)1480 412 451
sales@ttid.co.uk
www.ttid.co.uk

TTid.co.uk
THURLBY THANDAR
instrument distribution

ITECH Web

ITECH Facebook

ITECH LinkedIn

www.itechate.com