BATTERY TEST PROCEDURES
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DV POWER

Swedish manufacturer of various test equipment since 2000:

- Transformer test equipment
  - Winding resistance measurement
  - OLTC
  - Turns ratio
  - ....
- Circuit Breaker Test Equipment
  - Timing (O, C, OC, ...)
  - Resistance (static and dynamic)
  - Coils
  - MTV
  - ....
- Battery Test Equipment
  - Capacity
  - Internal Resistance (AC and DC)
  - Voltage
  - Temperature
  - ....

DV POWER - References

- Over **20 000 devices** sold worldwide
- Over 110 countries
- Major customers: Siemens, Tesla, ABB, Schneider Electric ....

In Turkey

- More than 130 devices
  - TEIAS
  - EUAS
  - KESIR Muhendislik
  - BEST
  - AKSA Enerji
  - OEDAS
  - TANAP
  - ...

Batteries

- Batteries are energy storage devices that degrade over time
- Batteries require periodic maintenance and testing
- Maintenance and testing procedures are defined by relevant standards:
  - IEC
  - IEEE
  - NERC

Ways to Reduce Life of Battery

- Overcharge
- Over discharge
- Excessive charge rates
- Excessive discharge rates
- Improper equalization
- Hot operational environment
- Cold operational environment
- Extended storage period
- Improper battery for application

Relevant standards

- **IEEE 450** - IEEE Recommended Practice for Maintenance, Testing, and Replacement of **Vented Lead-Acid** Batteries for Stationary Applications
- **IEEE 1106** - IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of **Vented Nickel-Cadmium** Batteries for Stationary Applications
- **IEEE 1188** - IEEE Recommended Practice for Maintenance, Testing, and Replacement of **Valve-Regulated Lead- Acid (VRLA)** Batteries for Stationary Applications
- **IEEE - P2962** - Recommended Practice for the Installation, Operation, Maintenance, Testing, and Replacement of **Li-ion Batteries** in Stationary Applications
- **IEC 62620** - Secondary cells and batteries containing alkaline or other nonacid electrolytes - Secondary **lithium cells and batteries** for use in industrial applications

IEEE 450 - VLA Batteries Inspections

Measurement	Monthly	Quarterly	Annually
Battery (String) Voltage	✔		
Charger Voltage & Current	✔		
Ambient temperature	✔		
Visual Inspection	✔		
Electrolyte Levels	✔		
Pilot Cell Voltage, Temperature, Specific gravity	✔		
Cell Temperature		✔ (10%)	
Cell Internal Ohmic			✔
Connection Resistance			✔
Capacity Test Intervals			25 % of expected service life

IEEE 1188 – VRLA Batteries Inspections

Measurement	Monthly	Quarterly	Annually
Battery (String) Voltage	✔		
Charger Current	✔		
Ambient temperature	✔		
Visual Inspection	✔		
Electrolyte Levels		✔	
All Cell Voltages		✔	
Cell Temperature		✔ (10%)	
Cell Internal Ohmic		✔	
Connection Resistance			✔
AC Ripple Current and Voltage			✔
Capacity Test Intervals			25 % of expected service life **2 years**

IEEE 1106 – Ni-Cd Batteries Inspections

Measurement	Quarterly	Semi-annually	Annually
Visual Inspection	✔		
Charger Output Current	✔		
Charger Output Voltage	✔		
String (Float) Voltage	✔		
All Cell Voltages		✔	
Cell Temperaure		✔ (10%)	
Cell Internal Ohmic	-	-	-
Connection Resistance			✔
Capacity Test Intervals			25 % of expected service life **2 years**

INDICATING PARAMETERS

- Measured change (voltage, current, etc) does not always lead to immediate and complete failure of battery cell
- Preceded by a deterioration in performance
- Indicating parameters:
  - Reduced Capacity
  - Increased Internal Resistance / Impedance
  - Increased Self-discharge
  - Overheating

Battery Test Types

- Visual inspection
- Specific gravity
- Float voltage and current
- Temperature
- Internal resistance
- Capacity test

What is a „good” battery

Voltage measurement

- Simple
- Unreliable information on battery condition
  - Good voltage ≠ good battery

B1: 12 V, 100 Ah → (charging) → U: 14.2 V

B2: 12 V, 70 Ah → (charging) → U: 14.2 V

→ No difference

Other parameters?

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Condition assessment parameters

Capacity

(Ah)

- <u>The most important</u> parameter for condition assessment
- The only 100%-reliable method to test your battery *(slow, but safe).*
- The key test according to IEEE standards.
  - Acceptance test
  - Periodically
  - If we suspect there is a problem

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Condition assessment parameters

Capacity

(Ah)

- The result is a number: C = I x t (Ah)
- Example:
  - Manufacturer: C_{10} = 1 200 Ah
  - Measured: C_{M10} = 1 134 Ah (94,5%) good?

- Yes, because 80% limit not breached
- 94,5% Ah capacity is still there

Effect of temperature - Temperature correction factor

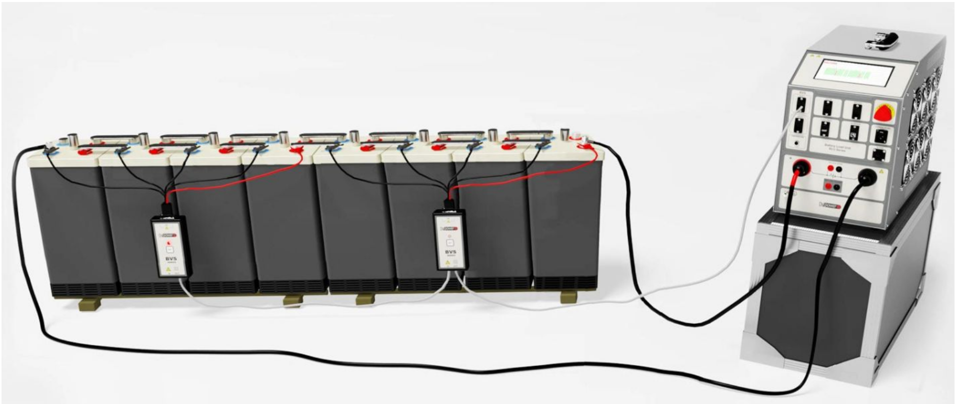
- Time correction factor (Kt) for temperatures other then 25 °C

Initial temperature (°C)	Initial temperature (°F)	Temperature correction factor K_T	Initial temperature (°C)	Initial temperature (°F)	Temperature correction factor K_T
4.4	40	0.670	26.1	79	1.007
7.2	45	0.735	26.7	80	1.011
10.0	50	0.790	27.2	81	1.017
12.8	55	0.840	27.8	82	1.023
15.6	60	0.882	28.3	83	1.030
18.3	65	0.920	28.9	84	1.035
18.9	66	0.927	29.4	85	1.040
19.4	67	0.935	30.0	86	1.045
20.0	68	0.942	30.6	87	1.050
20.6	69	0.948	31.1	88	1.055
21.1	70	0.955	31.6	89	1.060
21.7	71	0.960	32.2	90	1.065
22.2	72	0.970	35.0	95	1.090
22.8	73	0.975	37.8	100	1.112
23.4	74	0.980	40.6	105	1.140
23.9	75	0.985	43.3	110	1.162
24.5	76	0.990	46.1	115	1.187
25.0	77	1.000	46.1	120	1.210
25.6	78	1.002	—	—	—

Cell voltage measurements during the capacity test

Why it is important ?

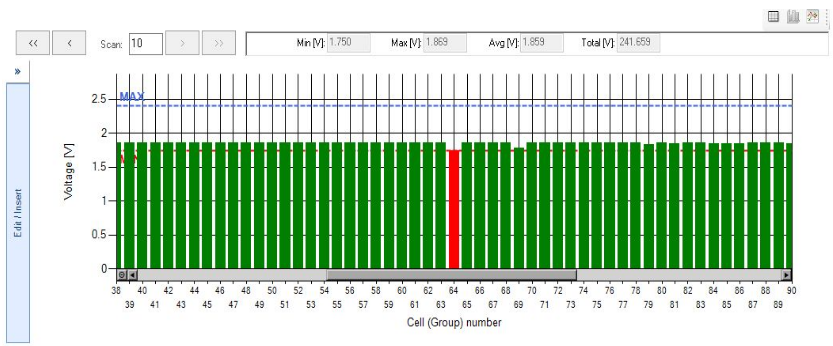
- **Increase lifetime** (replace bad cell, NOT the whole battery)
- Be sure that the battery keeps its specification.
- **Predict failures** (specifically the bad cells)
- Measure all cells at the same time – Possibility to compare cells with each others.
- Less risk that the battery is replaced too early

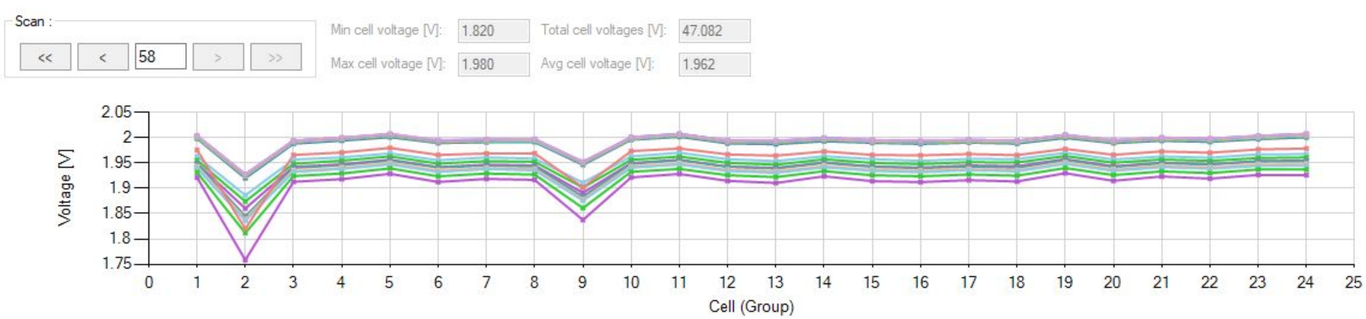


BLU-C + BVS-4 connection to battery string

Cell voltage measurements during the capacity test

- Cell Voltage deviation within a string





DV power Solutions for Battery Testing

Capacity Testers

BLU-T Series

0,9 – 70,5 V DC
Up to 350 A

BLU110T

BLU220T

BLU-A Series

5,25 – 500 V DC
Up to 240 A

BLU100A, BLU100L

BLU340A, BLU360V

BLU-C Series

3.0 – 800 V DC
Up to 300 A

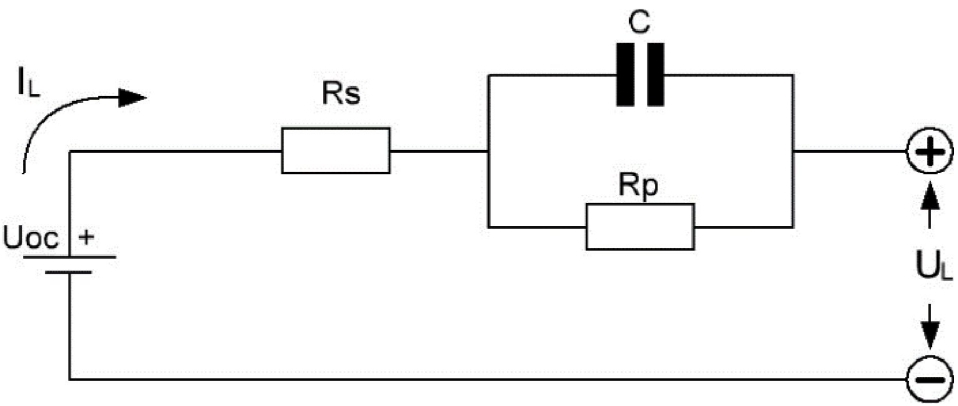
INTERNAL RESISTANCE TEST

Condition assessment parameters

Internal resistance
(mΩ)

AC method

- 1 kH current signal,
- Device measures u(t),



- How to interpret the result?

Condition assessment parameters

Internal resistance
(mΩ)

- The result is a number (mΩ)
- Example:

  Manufacturer: R_{nu} = 2,21 mΩ

  Measured: R_{mu} = 2,53 mΩ

- 15% difference – is it good?
- ΔR (15%) -> ΔC(15%)? NO
  - Compare all values with avarage value of R_u
  - Compare all values with previously measured values

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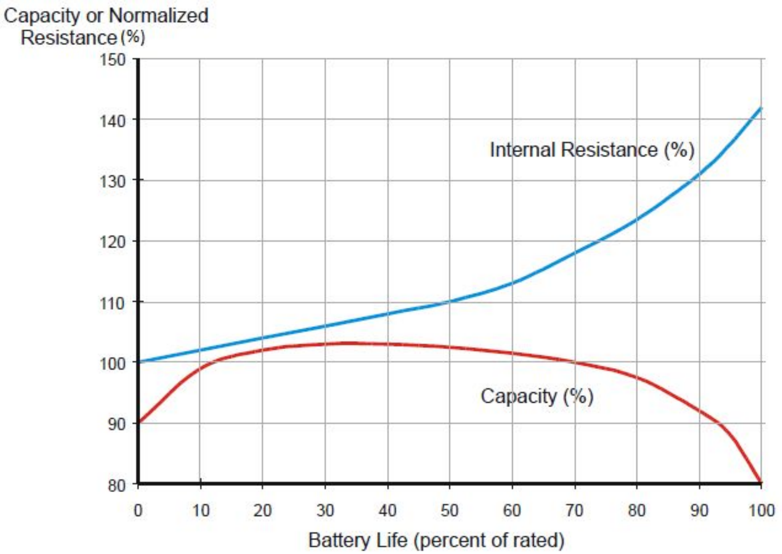
Solution – Internal Resistance

IBAR Model

- Hand-held model (1 kg)
- Injecting 1 kHz AC current signal into cell
  - Current value: 1,6 mA – 160 mA
- Resistant range:
  - 0 - 3,000 Ώ
- Voltage:
  - 6V/ 60V DC

Correlation Between Internal Resistance and Battery Capacity



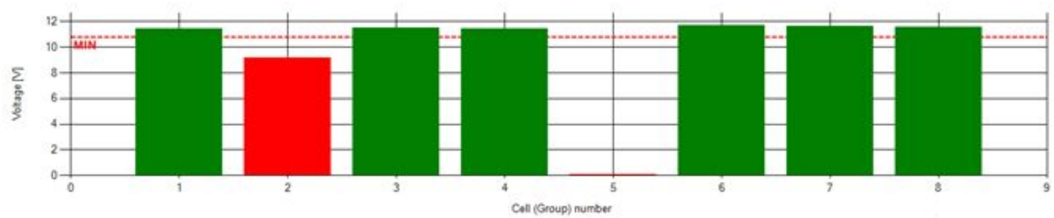
- Inversely proportional correlation between battery capacity and resistance (for lead-acid)

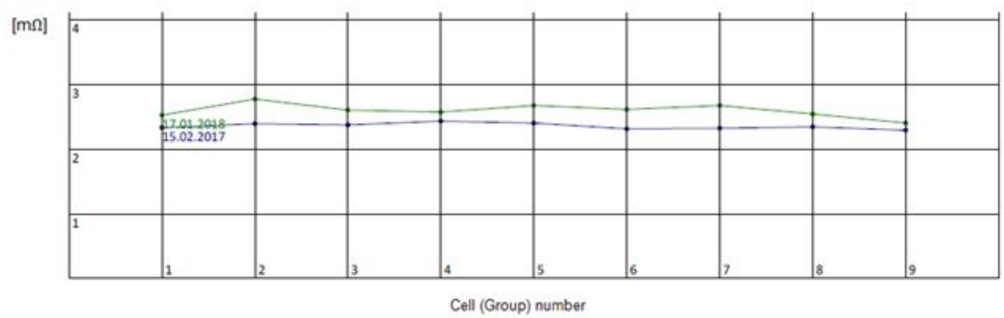
Correlation Between Internal Resistance and Battery Capacity

Factor	Internal cell resistance	Effect on capacity	Comments
Grid corrosion	Increase	Decrease	Natural aging process.
Grid swelling and expansion	Increase	Decrease	Loss of contact between active material and grid.
Loss of active material	Increase	Decrease	Active material sheds from plates, forming sediment.
Discharge	Increase	Decrease	Either self-discharge or discharge into a load.
Internal short circuits	Possible decrease followed by an increase	Decrease	Internal s/c's can cause resistance to decrease. If resistance subsequently increases this may cause self discharge which will cause the voltage to decrease.
Sulfation	Increase	Decrease	Caused by undercharging
Temperature decrease	Increase	Decrease	Low temperature degrades the cell chemical reaction, slows the chemical process, and limits available capacity.
Temperature increase	Decrease	Increase	High temperatures accelerate the cell chemical reaction, shorten the cell life, and increase the available capacity.

Correlation Between Internal Resistance and Battery Capacity

- After internal resistance measurement the condition of cell 5 was acceptable, but during the capacity testing the cell voltage dropped.





BATTERY TEST EQUIPMENT

Battery Monitoring System

- Designed for 24/7 real time monitoring of battery systems for various applications
- Monitors and logs battery cell and string parameters, as well as alarm conditions
- One module measures voltage of four cells
- One cell temperature channel per module
- String voltage & current, and ambient temperature measurement
- Use settable limits and acquisition intervals
- Logging of cell/battery parameters with data/time stamps
- Alarm conditions logging and alarm email alerts
- Export data for further analysis

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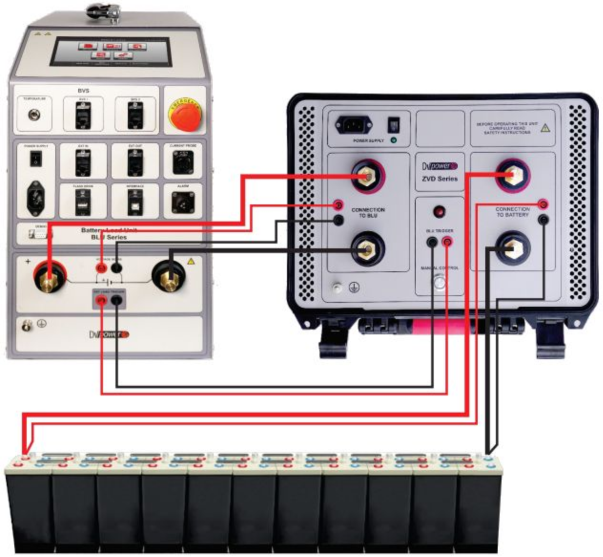
DV power Solutions for Recycling

BLU-C + ZVD System

- Applicable to batteries up to 1500 V
- Controlled constant current discharge down to 0 V (up to 60 A)
- 2-step process:
  - Discharge down to 0 V (BLU-C)
  - Battery Short-circuited (ZVD)



Thank you for your time!

Questions?

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