ESS Charging Event Analysis Report

DCIR Analysis and Current-based Clustering

Battery Software Lab

15-7월-2025

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Executive Summary

This report presents the analysis of ESS charging events from 2021 field data. The analysis includes automatic current-based clustering using K-means algorithm and DCIR (Direct Current Internal Resistance) calculation for each cluster. The results provide insights into charging patterns and resistance characteristics.

Analysis Parameters

Parameter	Value	Description
Battery Capacity	1024 Ah	Nominal capacity
Min Charge Duration	30 s	Minimum charging time
Max Power Std	10 kW	Maximum power stability

Max Current Std	10.24 A	Maximum current stability
Min Cluster Size	3	Minimum events per cluster
Max Clusters	6	Maximum number of clusters
Analysis Year	2021	Data period

Current-based Clustering Results

A total of 115 clusters were identified using K-means clustering. Each cluster represents a distinct charging current range. The clustering was performed based on average charging current values.

Cluster	C-rate	Events	Avg Current (A)	Description
event1	N/A	30	NaN	Low rate charging
event2	N/A	30	NaN	Low rate charging
event3	N/A	30	NaN	Low rate charging
event4	N/A	30	NaN	Low rate charging
event5	N/A	30	NaN	Low rate charging
event6	N/A	30	NaN	Low rate charging
event7	N/A	30	NaN	Low rate charging
event8	N/A	30	NaN	Low rate charging
event9	N/A	30	NaN	Low rate charging
event10	N/A	30	NaN	Low rate charging
event11	N/A	30	NaN	Low rate charging
event12	N/A	30	NaN	Low rate charging
event13	N/A	30	NaN	Low rate charging
event14	N/A	30	NaN	Low rate charging
event15	N/A	30	NaN	Low rate charging
event16	N/A	30	NaN	Low rate charging
event17	N/A	30	NaN	Low rate charging
event18	N/A	30	NaN	Low rate charging
event19	N/A	30	NaN	Low rate charging
event20	N/A	30	NaN	Low rate charging
event21	N/A	30	NaN	Low rate charging
event22	N/A	30	NaN	Low rate charging
event23	N/A	30	NaN	Low rate charging
event24	N/A	30	NaN	Low rate charging
event25	N/A	30	NaN	Low rate charging
event26	N/A	30	NaN	Low rate charging
event27	N/A	30	NaN	Low rate charging
event28	N/A	30	NaN	Low rate charging
event29	N/A	30	NaN	Low rate charging
event30	N/A	30	NaN	Low rate charging
event31	N/A	30	NaN	Low rate charging
event32	N/A	30	NaN	Low rate charging
event33	N/A	30	NaN	Low rate charging
event34	N/A	30	NaN	Low rate charging

event35	N/A	30	NaN	Low rate charging
event36	N/A	30	NaN	Low rate charging
event37	N/A	30	NaN	Low rate charging
event38	N/A	30	NaN	Low rate charging
event39	N/A	30	NaN	Low rate charging
event40	N/A	30	NaN	Low rate charging
event41	N/A	30	NaN	Low rate charging
event42	N/A	30	NaN	Low rate charging
event43	N/A	30	NaN	Low rate charging
event44	N/A	30	NaN	Low rate charging
event45	N/A	30	NaN	Low rate charging
event46	N/A	30	NaN	Low rate charging
event47	N/A	30	NaN	Low rate charging
event48	N/A	30	NaN	Low rate charging
event49	N/A	30	NaN	Low rate charging
event50	N/A	30	NaN	Low rate charging
event51	N/A	30	NaN	Low rate charging
event52	N/A	30	NaN	Low rate charging
event53	N/A	30	NaN	Low rate charging
event54	N/A	30	NaN	Low rate charging
event55	N/A	30	NaN	Low rate charging
event56	N/A	30	NaN	Low rate charging
event57	N/A	30	NaN	Low rate charging
event58	N/A	30	NaN	Low rate charging
event59	N/A	30	NaN	Low rate charging
event60	N/A	30	NaN	Low rate charging
event61	N/A	30	NaN	Low rate charging
event62	N/A	30	NaN	Low rate charging
event63	N/A	30	NaN	Low rate charging
event64	N/A	30	NaN	Low rate charging
event65	N/A	30	NaN	Low rate charging
event66	N/A	30	NaN	Low rate charging
event67	N/A	30	NaN	Low rate charging
event68	N/A	30	NaN	Low rate charging
event69	N/A	30	NaN	Low rate charging
event70	N/A	30	NaN	Low rate charging
event71	N/A	30	NaN	Low rate charging
event72	N/A	30	NaN	Low rate charging
event73	N/A	30	NaN	Low rate charging
event74	N/A	30	NaN	Low rate charging
event75	N/A	30	NaN	Low rate charging
event76	N/A	30	NaN	Low rate charging
event77	N/A	30	NaN	Low rate charging
event78	N/A	30	NaN	Low rate charging
event79	N/A	30	NaN	Low rate charging

event80	N/A	30	NaN	Low rate charging
event81	N/A	30	NaN	Low rate charging
event82	N/A	30	NaN	Low rate charging
event83	N/A	30	NaN	Low rate charging
event84	N/A	30	NaN	Low rate charging
event85	N/A	30	NaN	Low rate charging
event86	N/A	30	NaN	Low rate charging
event87	N/A	30	NaN	Low rate charging
event88	N/A	30	NaN	Low rate charging
event89	N/A	30	NaN	Low rate charging
event90	N/A	30	NaN	Low rate charging
event91	N/A	30	NaN	Low rate charging
event92	N/A	30	NaN	Low rate charging
event93	N/A	30	NaN	Low rate charging
event94	N/A	30	NaN	Low rate charging
event95	N/A	30	NaN	Low rate charging
event96	N/A	30	NaN	Low rate charging
event97	N/A	30	NaN	Low rate charging
event98	N/A	30	NaN	Low rate charging
event99	N/A	30	NaN	Low rate charging
event100	N/A	30	NaN	Low rate charging
event101	N/A	30	NaN	Low rate charging
event102	N/A	30	NaN	Low rate charging
event103	N/A	30	NaN	Low rate charging
event104	N/A	30	NaN	Low rate charging
event105	N/A	30	NaN	Low rate charging
event106	N/A	30	NaN	Low rate charging
event107	N/A	30	NaN	Low rate charging
event108	N/A	30	NaN	Low rate charging
event109	N/A	30	NaN	Low rate charging
event110	N/A	30	NaN	Low rate charging
event111	N/A	30	NaN	Low rate charging
event112	N/A	30	NaN	Low rate charging
event113	N/A	30	NaN	Low rate charging
event114	N/A	30	NaN	Low rate charging
event115	N/A	30	NaN	Low rate charging

DCIR Analysis Results

DCIR (Direct Current Internal Resistance) analysis was performed for each cluster. The analysis includes time-based DCIR calculations at 1s, 3s, 5s, 10s, 30s, and 50s intervals, as well as DCIR difference calculations to assess resistance evolution during charging.

Cluster: event1 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event2 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event3 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event4 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event5 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event6 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event7 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event8 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event9 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event10 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event11 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event12 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event13 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event14 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event15 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event16 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event17 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event18 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event19 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event20 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Cluster: event23 (30 events)

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Cluster: event25 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event30 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event31 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Cluster: event40 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event41 (30 events)

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Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event44 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event45 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event46 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event47 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event48 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event59 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event60 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event61 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event63 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event65 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event66 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event67 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event68 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

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Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event70 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event71 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event72 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event73 (30 events)

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Cluster: event74 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event75 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event76 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event77 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event78 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event79 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event80 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event81 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event82 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event83 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event84 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event85 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event86 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event87 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event88 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event89 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event90 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event91 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event92 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event93 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event94 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event95 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event96 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event97 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event98 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event99 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event100 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event101 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event102 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event103 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event104 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event105 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event106 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event107 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event108 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event109 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event110 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event111 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event112 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event113 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event114 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Cluster: event115 (30 events)

Time Interval	Mean DCIR (mΩ)	Std DCIR (mΩ)	Min DCIR (mΩ)	Max DCIR (mΩ)

Key Findings

1. **Current Distribution**: The analysis reveals distinct charging patterns with 115 different current ranges identified.\n\n2. **DCIR Characteristics**: Each cluster shows unique DCIR evolution patterns during charging, indicating different resistance behaviors at various current levels.\n\n3. **Charging Efficiency**: Lower current clusters typically show more stable DCIR values, while higher current clusters may exhibit more variation.

Conclusions

The automatic clustering approach successfully identified distinct charging patterns in the ESS field data. The DCIR analysis provides valuable insights into resistance characteristics at different charging rates. This information can be used for optimizing charging strategies and monitoring battery health.