CHAPTER 1: INTRODUCTION

The increased deployment of Battery Energy Storage Systems (BESS) in grid-connected environments plays a vital role in enhancing grid reliability, integrating renewable energy, and improving peak load management. However, their performance is significantly challenged by various types of battery faults. These faults can deteriorate the lifespan, performance, and safety of the entire power system. Therefore, understanding the generation, detection, classification, and mitigation of such faults is imperative.

CHAPTER 2: DETAILED DESCRIPTION OF BATTERY FAULTS

2.1 Internal Short Circuit Fault

- Generation: Caused due to separator damage or lithium dendrite growth that bridges the electrodes internally.

- Detection: Sudden temperature rise, drop in terminal voltage, and current anomalies; often detected using voltage/current sensors and thermal imaging.

- Classification: Classified as critical and immediate; sometimes confused with external shorts unless internally isolated.

- Mitigation: Advanced Battery Management Systems (BMS), thermal cutoff mechanisms, and internal cell fuses.

2.2 Overcharge Fault

- Generation: Occurs when charging voltage or current exceeds the safe limit, often due to BMS failure or charger malfunction.

- Detection: Measured using voltage sensors and monitored via charging profiles.

- Classification: Chronic fault; may lead to thermal runaway if unchecked.

- Mitigation: Voltage clamps, charge cutoffs in BMS, redundancy in charging control.

2.3 Overdischarge Fault

- Generation: Happens when the battery is discharged beyond its minimum voltage threshold.

- Detection: Voltage monitoring, SOC estimation algorithms.

- Classification: Medium severity; can be misclassified as capacity loss without accurate estimation.

- Mitigation: SOC limits enforced by BMS, load-shedding during critical levels.

2.4 Thermal Runaway Fault

- Generation: Triggered by internal short circuit or overcharge conditions causing uncontrolled temperature rise.

- Detection: Thermal sensors, sudden voltage drop, gas sensor feedback.

- Classification: Catastrophic; escalates from other fault types.

- Mitigation: Phase Change Materials (PCM), active thermal management, early thermal runaway models.

2.5 Open Circuit Fault

- Generation: Arises from disconnected terminals, broken welds, or corroded connectors.

- Detection: Detected as voltage spike/drop, abnormal current flow.

- Classification: Often misinterpreted as low state of charge.

- Mitigation: Redundant connections, mechanical stability improvements, contact monitoring.

2.6 SOC Imbalance

- Generation: Uneven charging/discharging due to non-uniform cell characteristics.

- Detection: Cell-level SOC estimation and comparison.

- Classification: Subtle; builds up over cycles.

- Mitigation: Passive or active cell balancing, advanced equalization control.

2.7 Voltage Drift

- Generation: Internal aging or degradation leads to cells drifting in voltage under same conditions.

- Detection: Long-term voltage logging, impedance spectroscopy.

- Classification: Chronic drift fault.

- Mitigation: Pre-conditioning, periodic calibration, predictive models.

2.8 External Short Circuit

- Generation: Due to external wiring faults, accidental conductive bridging.

- Detection: High current detection, fuse blowouts.

- Classification: Acute external fault.

- Mitigation: Fast-blow fuses, short-circuit protection relays.

2.9 Connector Faults / Loose Contacts

- Generation: Mechanical vibration, thermal cycling, poor assembly.

- Detection: Voltage oscillation, sudden drops in current output.

- Classification: Intermittent fault.

- Mitigation: Mechanical ruggedization, contact force monitoring, automated alerts.

2.10 Controller/BMS Fault

- Generation: Firmware bugs, hardware failures, sensor misreadings.

- Detection: Diagnostic self-checks, cross-verification with physical sensors.

- Classification: Silent but critical; misclassifies other faults.

- Mitigation: Redundant controllers, robust validation logic, watchdog timers.

CHAPTER 3: CONCLUSION

Battery faults in grid-connected systems can lead to severe grid disturbances and potential hazards if not addressed properly. This report has comprehensively covered the major types of battery faults along with their detection, classification, and mitigation mechanisms. Future work can focus on AI-integrated BMS designs and predictive fault analytics.

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