Distributed Control for Interlinked DC Microgrids

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Background and Objectives

➢ **PROJECT PROFILE**
Topic: Grid Resilience & Reliability
Vertical: Safety & Reliability
Strategic Pathway: Optimize
Project Duration: FY25-FY26

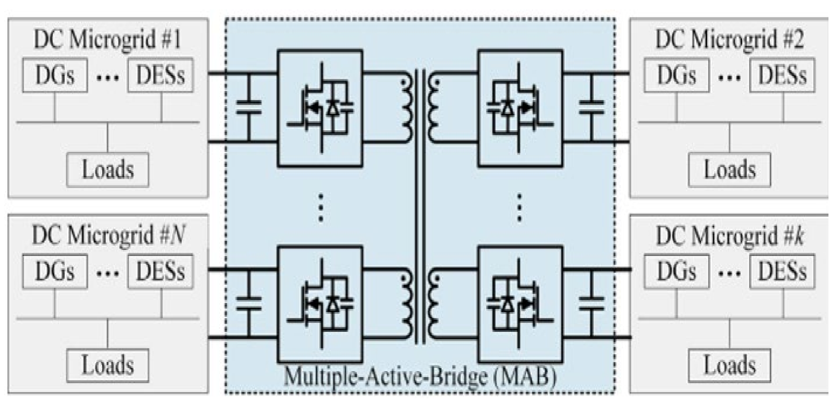


Figure (1) – Multi-active-bridge / Converter Schematic.

➢ Conventional tie-line interconnection suffers from voltage-level constraints, complex interconnection, and cascading-failure risks. Multi-active-bridge / Triple Active Bridge Converter (TABC) interconnection provides galvanic isolation, multi-voltage flexibility, and flexible power routing.

➢ However, TABC-interlinked DC Microgrids (DC-MGs) have fast high-order dynamics and strong multi-port coupling.

➢ Existing methods often rely on fault detection and controller switching, causing transient delay.

➢ Objective: to develop a distributed resilient control strategy for continuous operation under TABC failure, MG isolation, and communication faults.

Proposed Distributed Resilient Framework

➢ Scalable distributed resilient control: Establishes inherent multi-port coordination for energy routing across different voltage levels.

➢ Continuous voltage regulation under multi-point faults: Healthy ports autonomously redistribute energy during source or converter outages.

➢ Unified architecture without detect-then-switch: Eliminates explicit fault detection and controller reconfiguration.

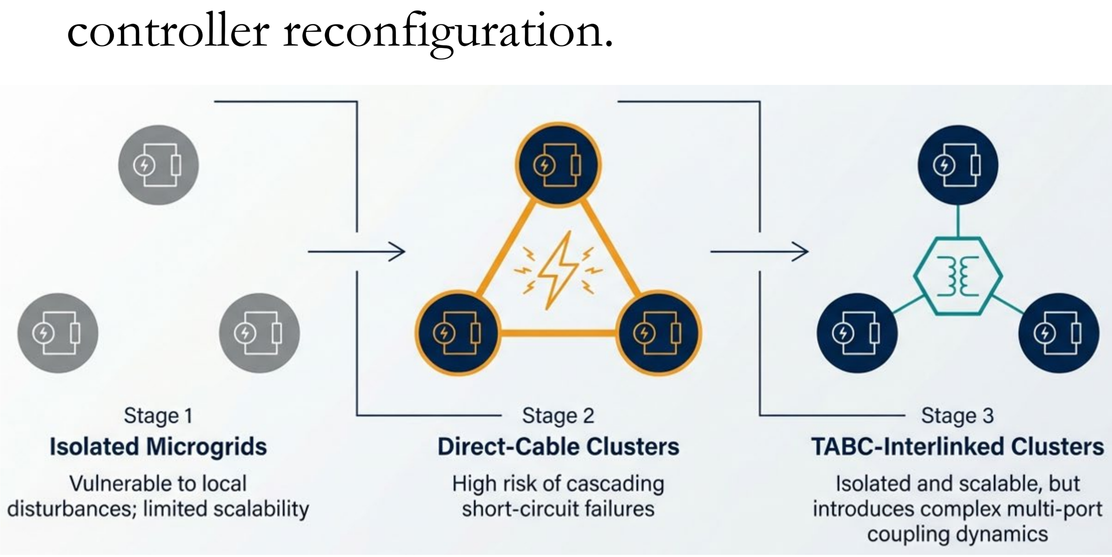


Figure (2) – Evolution of DC Microgrid Interconnection Architecture.

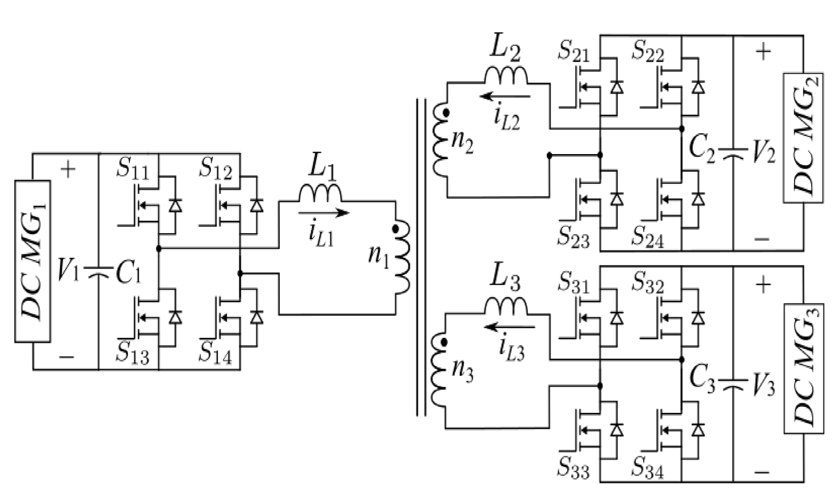


Figure (3) – TABC. Power Circuit

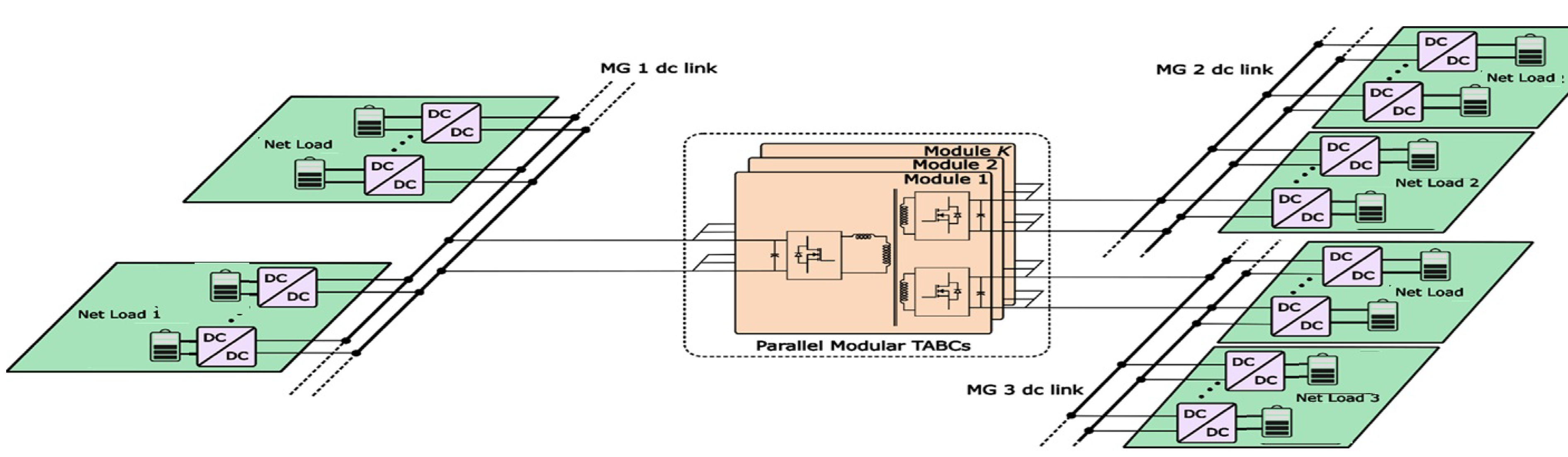


Figure (4) – Networked DC Microgrids System architecture.

Proposed Control Strategies

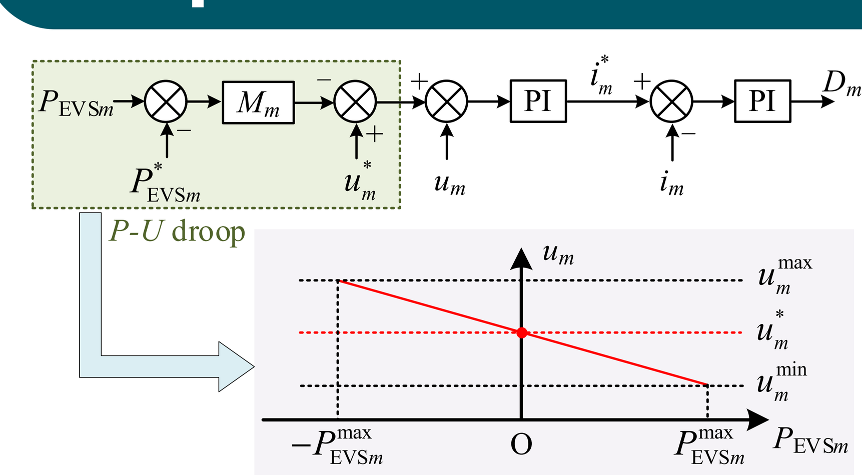


Figure (5) – DC MG control diagram.

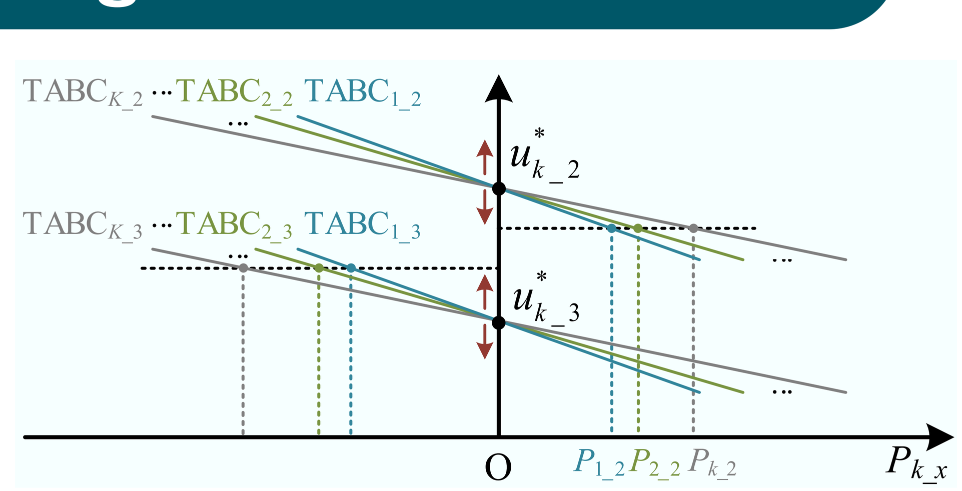


Figure (6) – TABC converter control diagram.

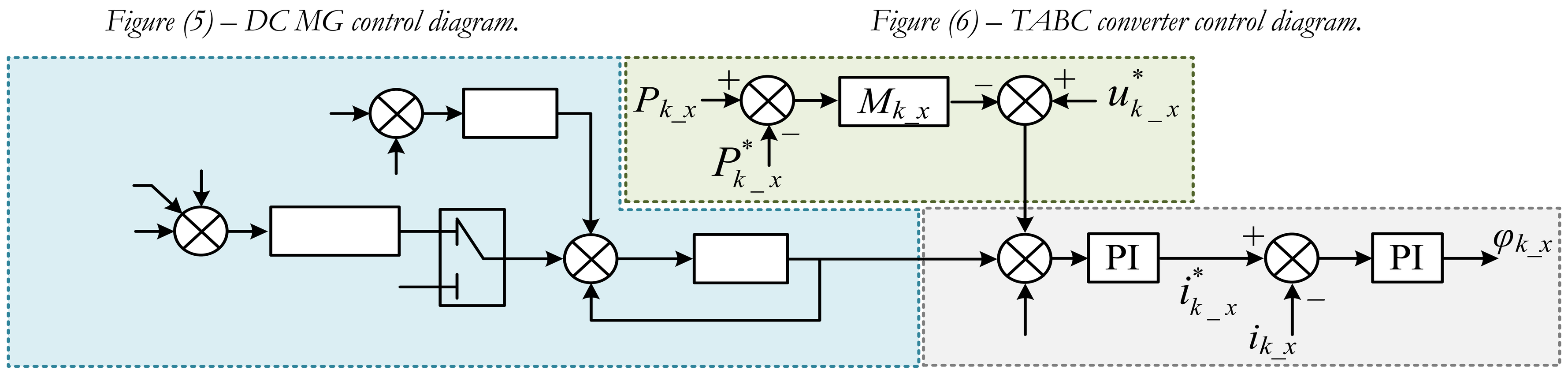


Figure (7) – Distributed TAB Control Diagram.

Resilient Operation Scenarios and HIL Setup

➢ The test system consists of two TABCs interlinking three DC MGs(or Equivalent Voltage Source – EVS) equipped with battery load, and local dc loads.

Case	Scenario	Purpose
Case 1	Normal operation	Proportional battery load & TABC power sharing
Case 2	TABC failure	Remaining TABC compensates lost power

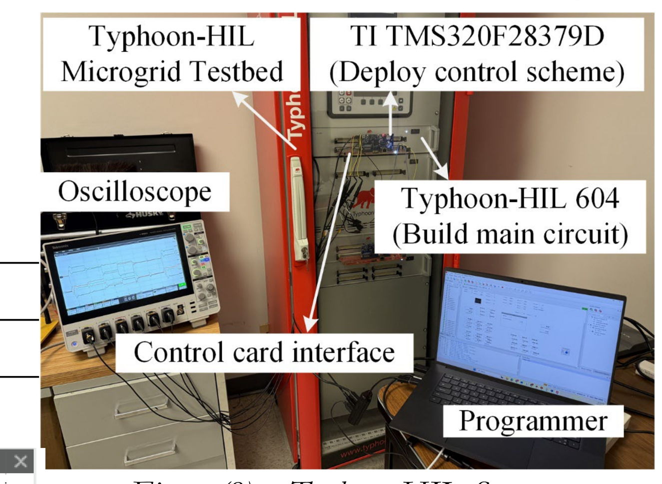
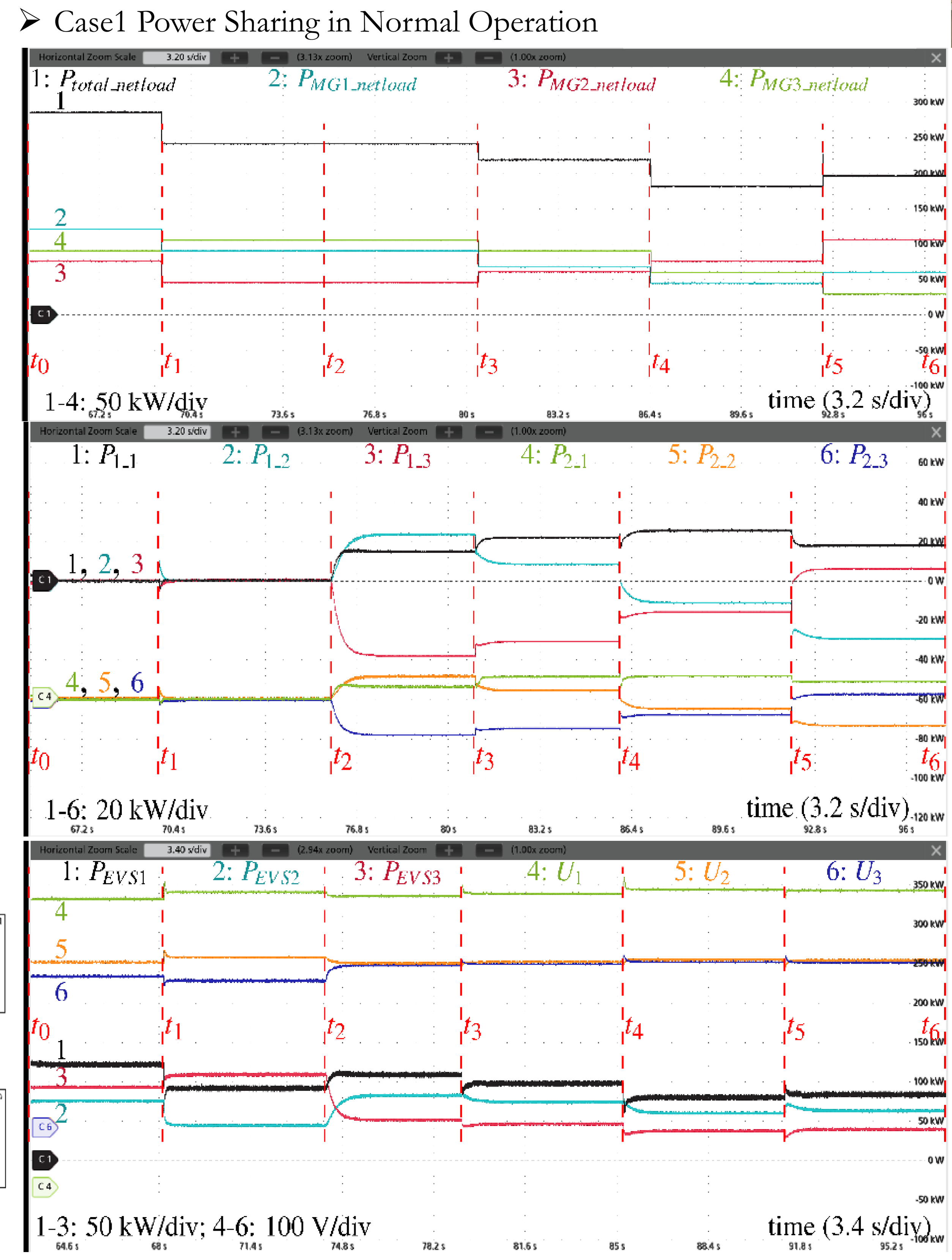


Figure (8) – Typhoon HIL Setup

➢ Case1 Power Sharing in Normal Operation

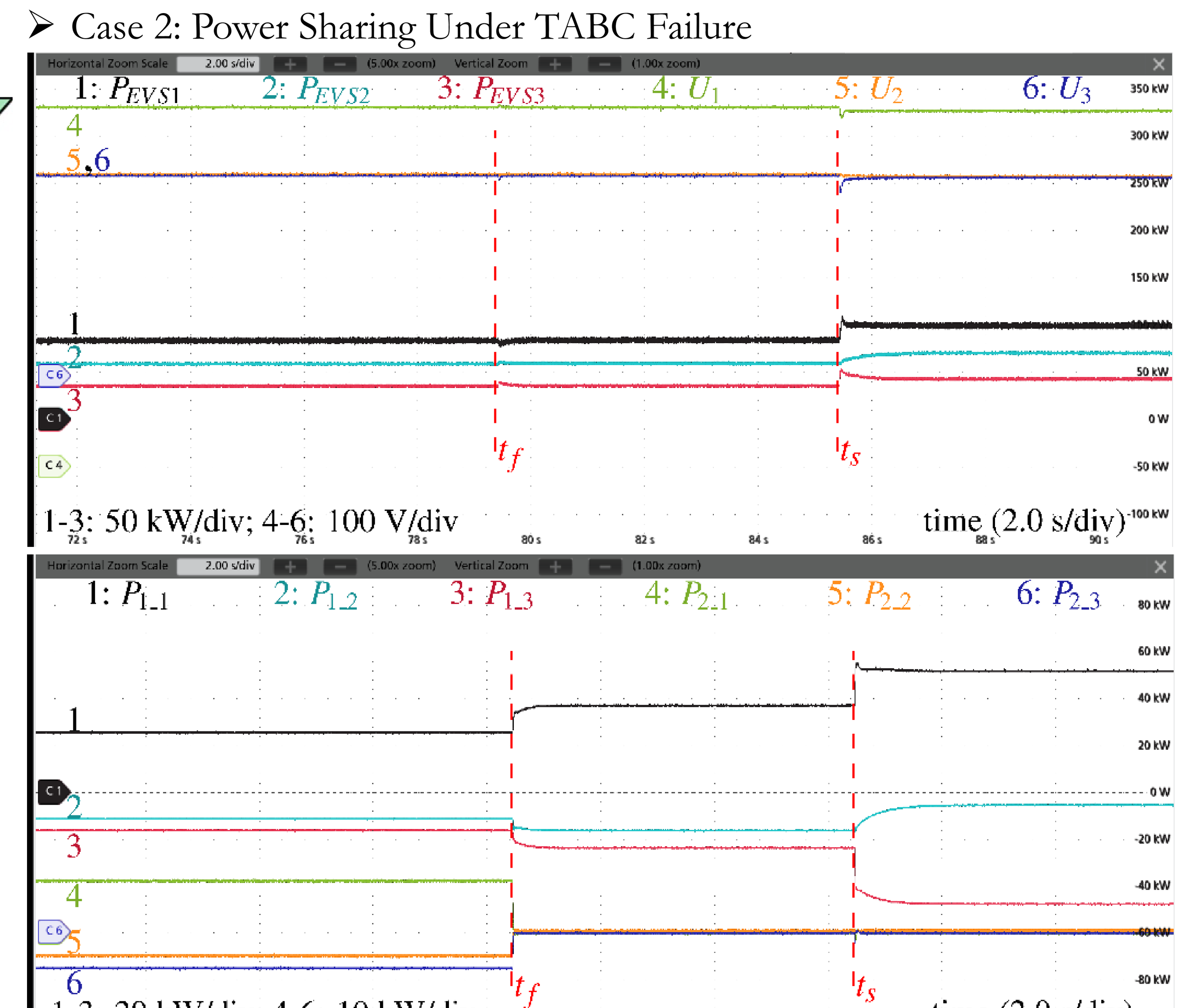


Case 1 Analysis:

- Initially, the three dc MGs operate independently, and each EVS supports its own local load.
- Once the TABCs are enabled at t_2, power exchange is established among the MGs.
- EVSs automatically to share the total load according to their rated capacities (4:3:2) via TABCs coordination .
- The two TABCs also share the exchanged power proportionally with a 2:1 rating ratio.
- The dc bus voltages of the three MGs remain balanced in per-unit values.

Conclusion: Case 1 validates proportional battery sharing with 4:3:2 rating ratio and proportional TABC sharing with 2:1 rating ratio under load steps. All energy storage share the total net load proportionally and TAB converters deliver power proportionally, responding to fast net load step changes.

➢ Case 2: Power Sharing Under TABC Failure



Case 2 Analysis:

- At T= t_f, one TABC is lost.
- The failed TABC output drops to zero, while the healthy TABC rapidly increases power transfer.
- EVS power sharing is preserved, and dc bus voltages remain stable during the fault transition.
- When MG3 load increases at t_s, the remaining TABC and EVSs automatically redistribute power.

Conclusion: When TABC2 fails, power reduced to zero. TAB 1 quickly compensated and only small disturbances observed on system voltage, ensuring continuous power exchange.

Conclusions and Future Work

➢ An autonomous distributed control framework is developed for TABC-interlinked DC microgrids to achieve proportional power sharing and resilient operation.

➢ The proposed strategy eliminates explicit fault detection and controller reconfiguration while maintaining voltage regulation under converter faults, source outages, MG isolation, and communication disturbances. HIL validation confirms effective power coordination across normal and faulted operating conditions.

➢ Future work will focus on large-scale microgrid clusters, adaptive control tuning, long-duration experimental validation, and integration with higher-level energy management.

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