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FOUNDATIONS OF RESILIENT CYBER-PHYSICAL SYSTEMS

# Fault and Attack Tolerant Control - Power Systems

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# Power systems background

* Current paradigm: preventive control.
  * *N-1* criterion: operate so system can survive largest *credible* event.
* Future: corrective control.
  * Use controllable resources to steer the system through (possibly unanticipated) events.
* Our focus: cascade mitigation.
  * Assume the system is transiently (10 second timeframe) stable.
  * Exploit thermal inertia inherent in transmission line conductors.

# Control strategy

* Use model predictive control (MPC) to:
  * Control generation, electrical energy storage, wind-spill, FACTS, load.
  * Subject to ramp-rate limits, physical limits.
* Hierarchical control:
  * Level 1: optimal power flow (with energy storage).
  * Level 2: MPC drives to set-points determined by Level 1.
* Model:
  * Linear formulation, currently use "DC power flow" for network model.
  * Convex relaxation of quadratic losses, provably tight at optimal.



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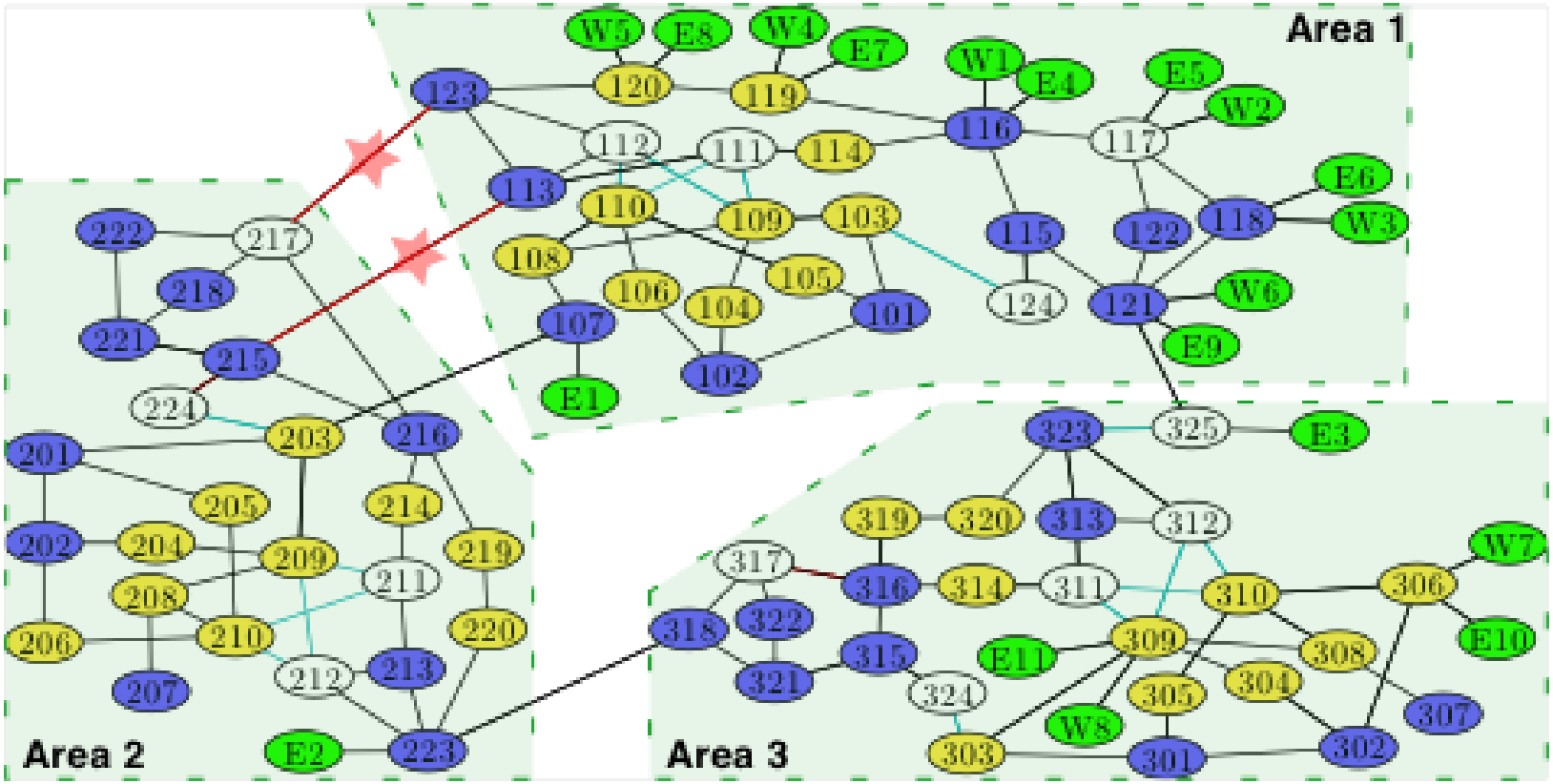
# Test case

* IEEE RTS-96 system, double-line outage.



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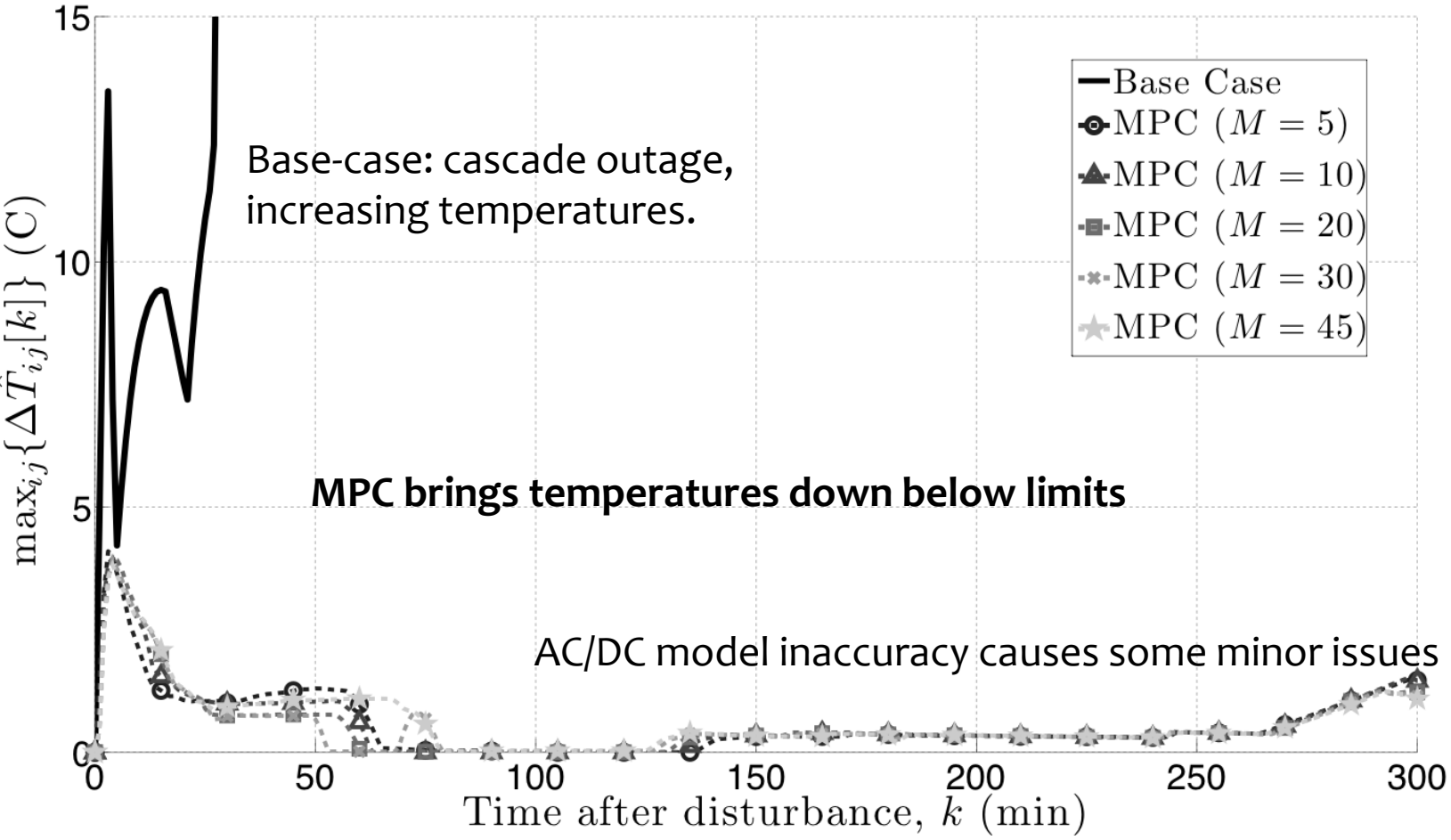
# Test case: max line temperatures



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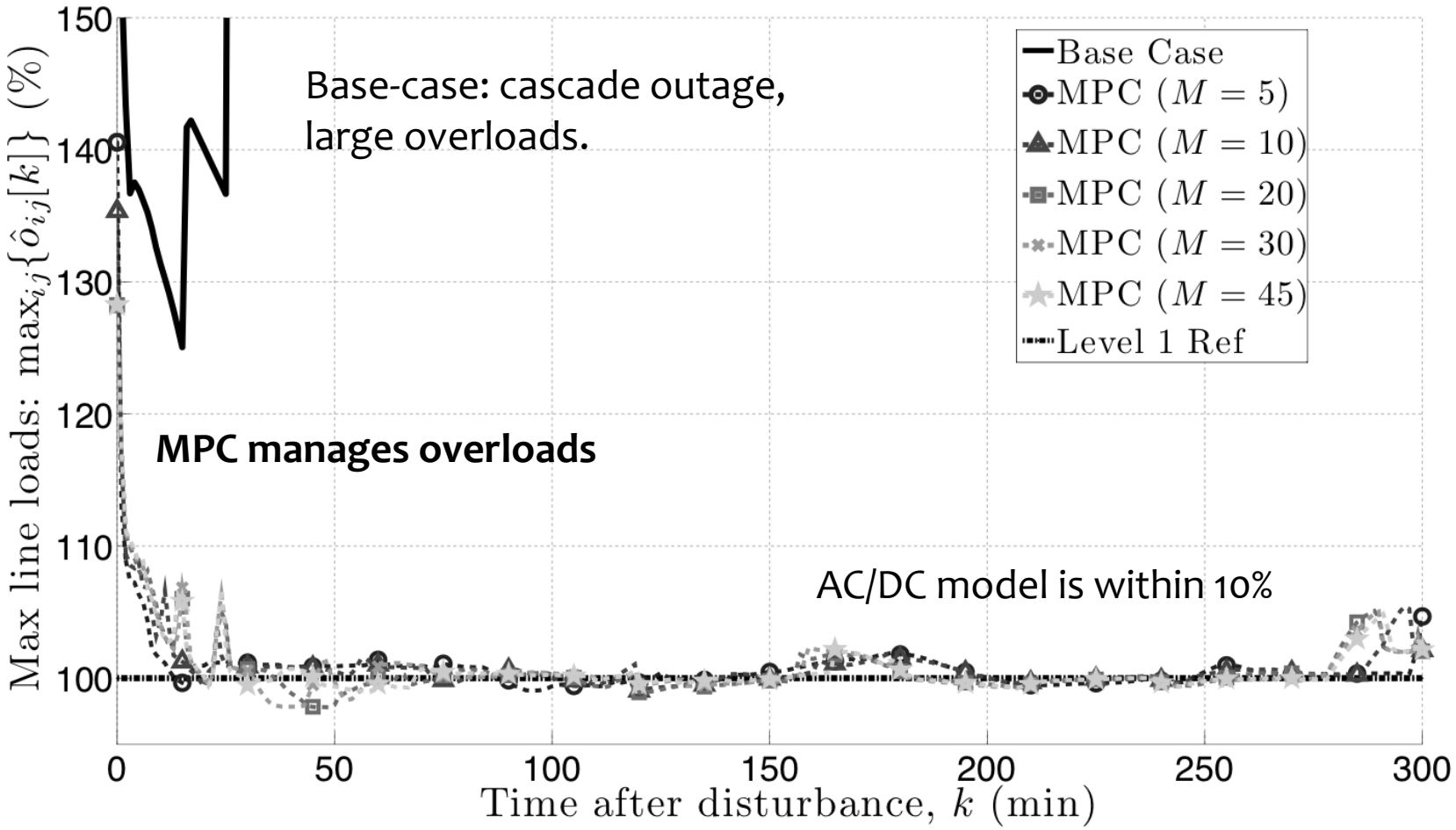
# Test case: max line power overloads

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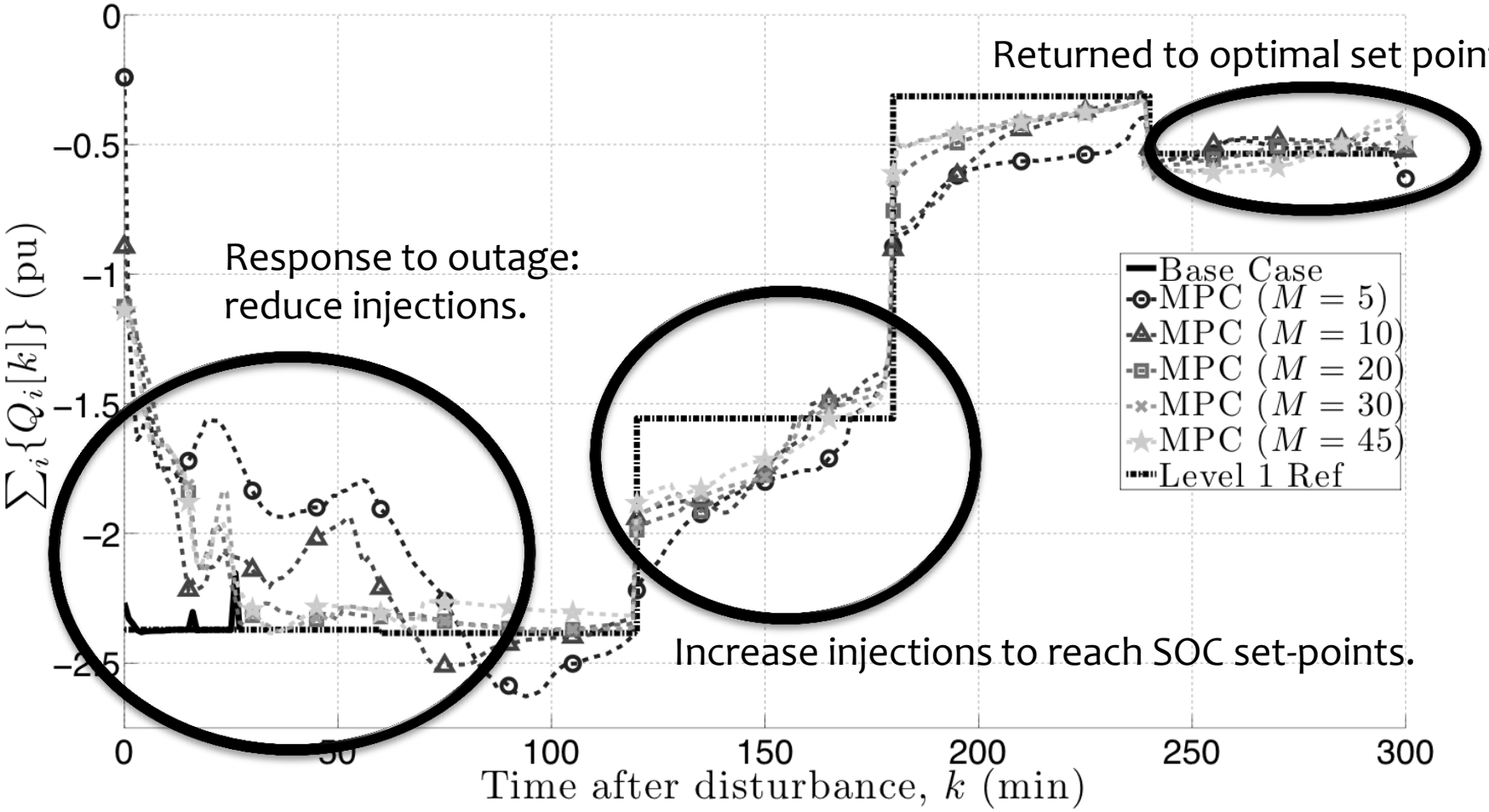
# Test case: aggregate storage injections

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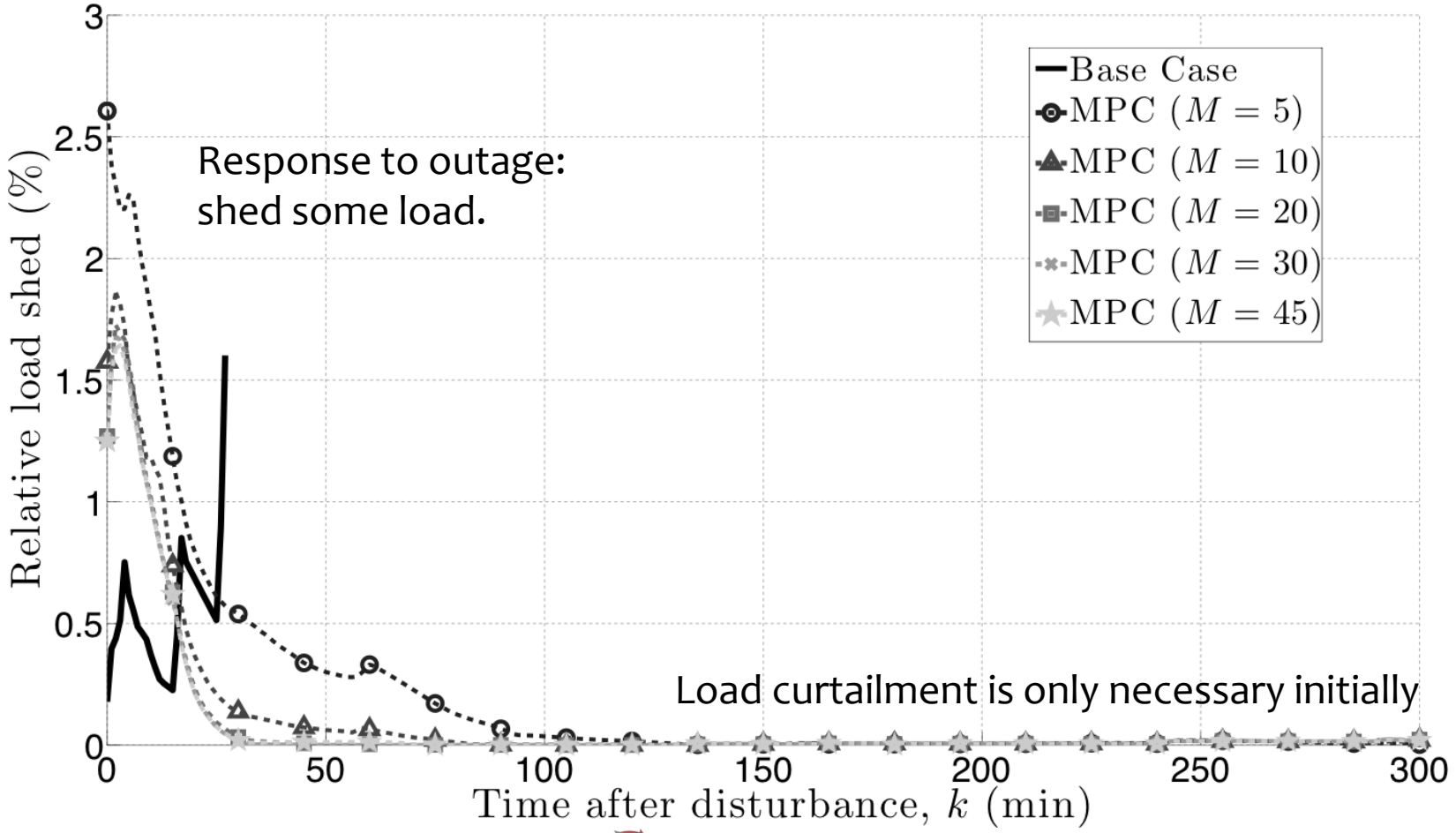
# Test case: aggregate load curtailment

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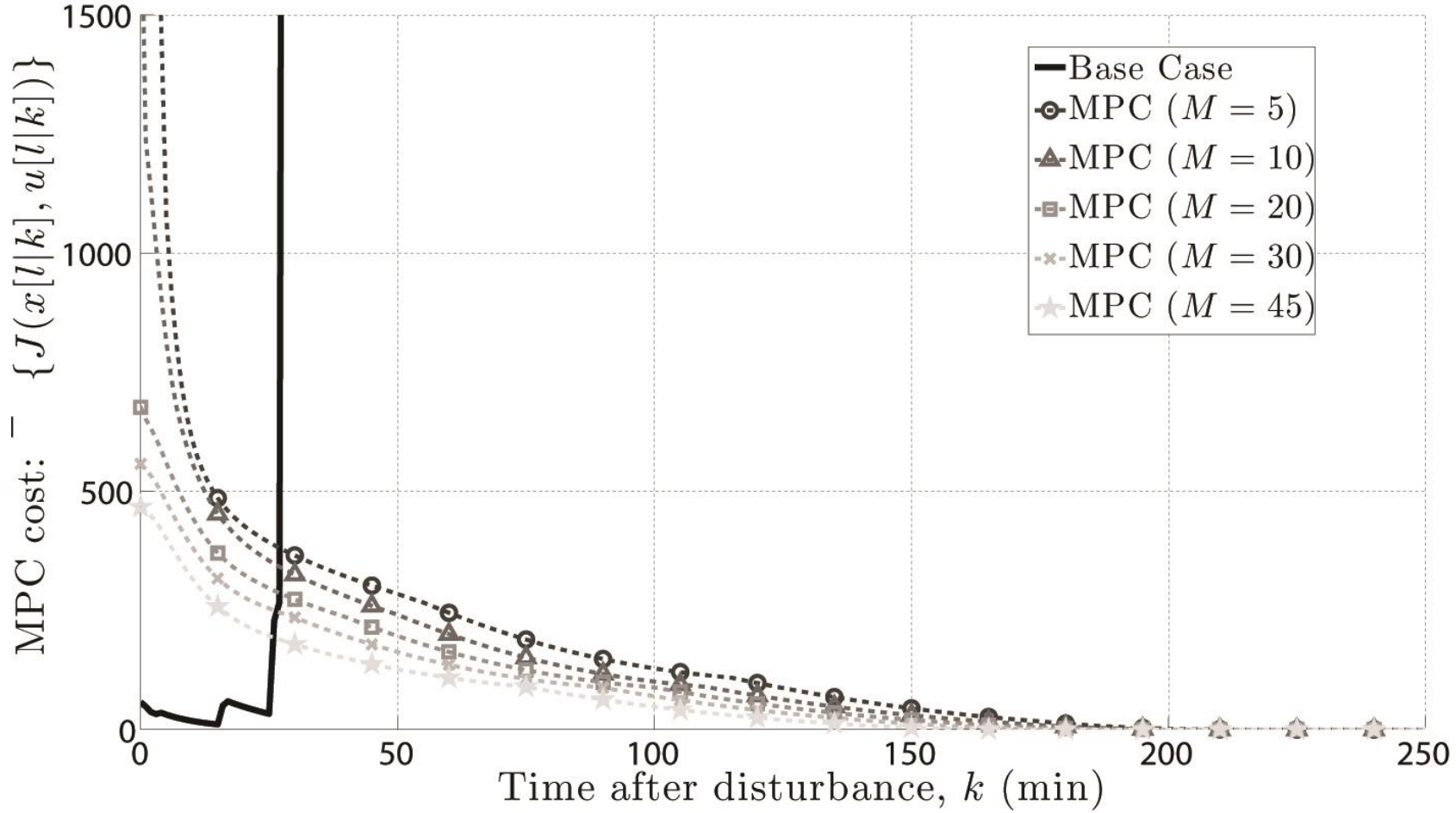
# Test case: MPC cost

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