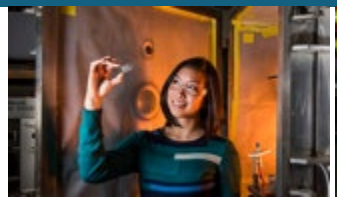
Sandia National Laboratories

Grid Stability Using Distributed Energy Storage



PRESENTED BY

David Schoenwald

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Project Overview

Problem:

- Large generation and load centers separated by long transmission corridors can develop inter-area oscillations
- Poorly damped inter-area oscillations jeopardize grid stability and can lead to widespread outages during high demand
- To prevent this, utilities constrain power flows well below transmission ratings ➔ inefficient

Objectives:

- Construct closed-loop control strategies deployed on energy storage systems located at many sites on the grid
- Investigate tradeoffs in sizing, siting, network limitations, network security, and ES availability on control schemes
- Design supervisory systems to ensure “Do No Harm” to the grid

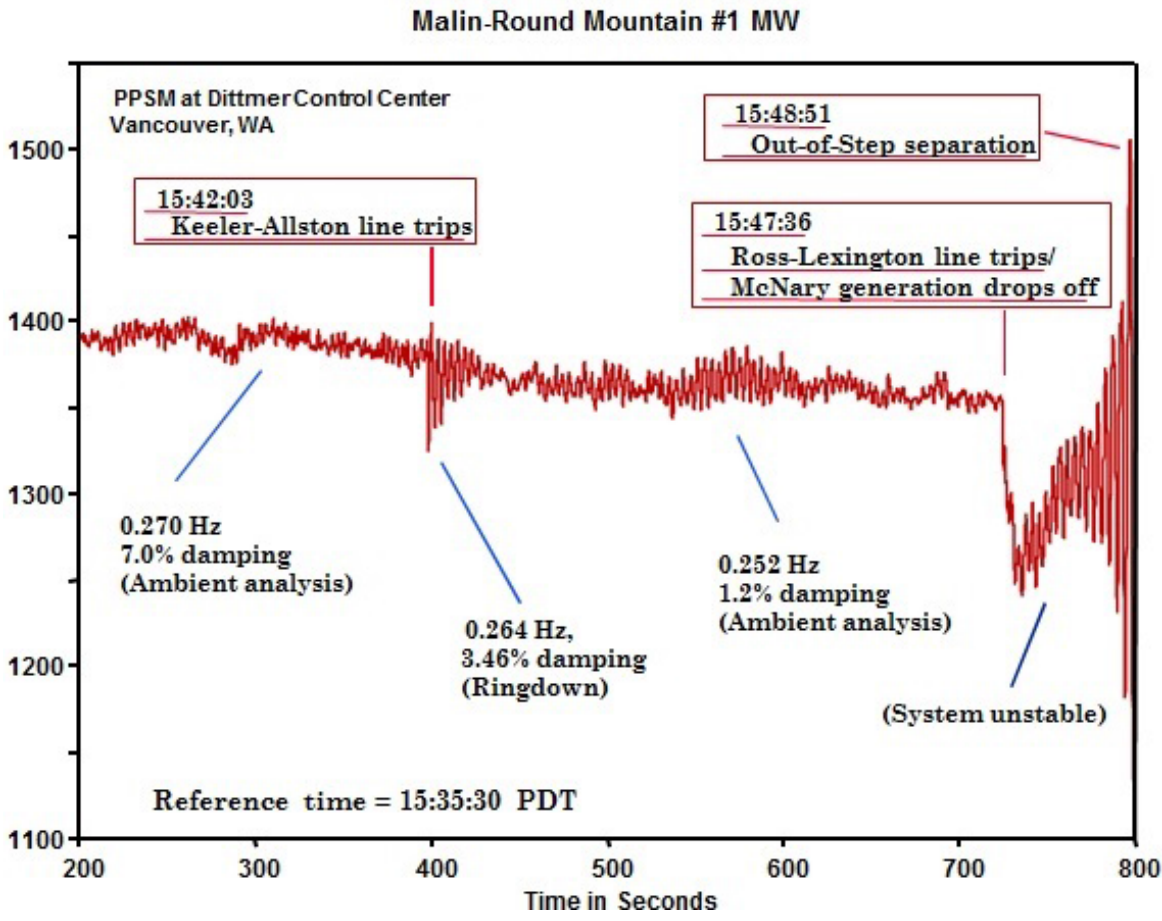
Potential Benefits:

- Improved grid reliability
- Additional contingency for stressed grid conditions
- Avoided costs from a system-wide blackout (>> $1B)
- Reduced or postponed need for new transmission capacity: $1M–$10M/mile
- Helps meet growing demand by enabling higher power flows on congested corridors

Wide-Area Power System Oscillations

- Low frequency (0.2-1 Hz) oscillations characteristic of interconnected power systems with synchronous generators excited by normal variations in system load.
- Must be damped effectively to maintain secure and stable system operation.
- Can lead to instability and system breakup if poorly damped.
- Recent availability of wide-area measurement systems has improved the effectiveness of wide-area damping control schemes.

Western Interconnection Breakup August 10, 1996



This Project Leverages BPA Damping Controller Project

- First successful demonstration of wide-area control using real-time PMU feedback in North America.
- Control signal is the modulation of real power flow through the Pacific DC Intertie (PDCI).
- Experience gained in networked controls can be leveraged by other network-enabled assets, including energy storage.
- Supervisory system design can be adapted to other real-time grid control systems to ensure “Do No Harm”.

2017 R&D 100 Award Winner

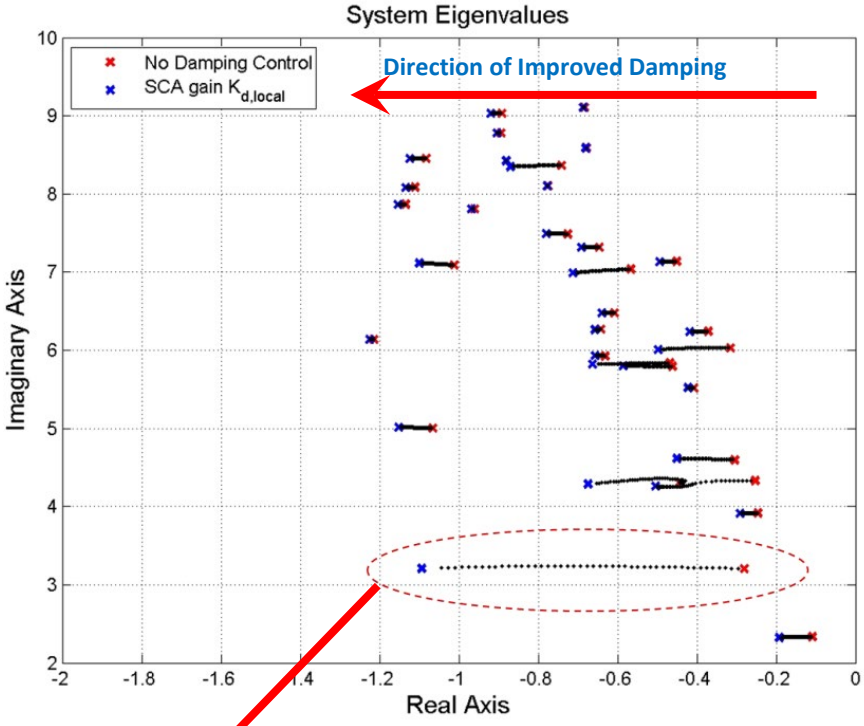
Distributed Control Using Energy Storage Sites

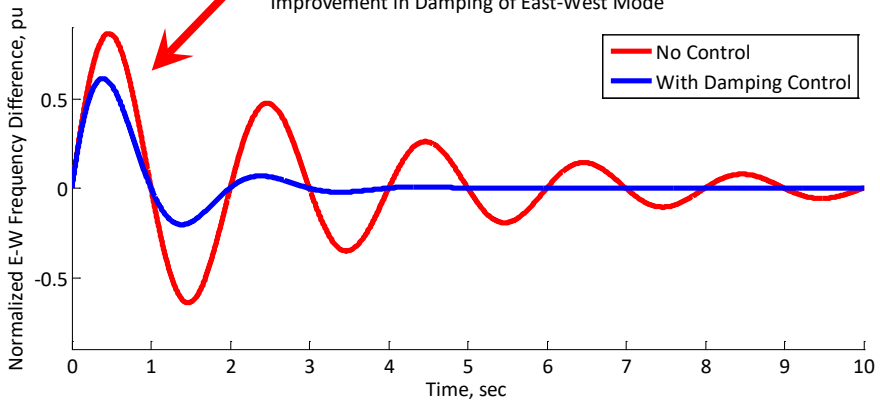
Advantages:

- Robust to single points of failure
- Controllability of multiple modes
- Size/location of a single site not as critical as more energy storage is deployed on grid
- With 10s of sites engaged, single site power rating ≈ 1 MW can provide improved damping
- Control signal is energy neutral and short in time duration ➔ storage sites can perform other applications

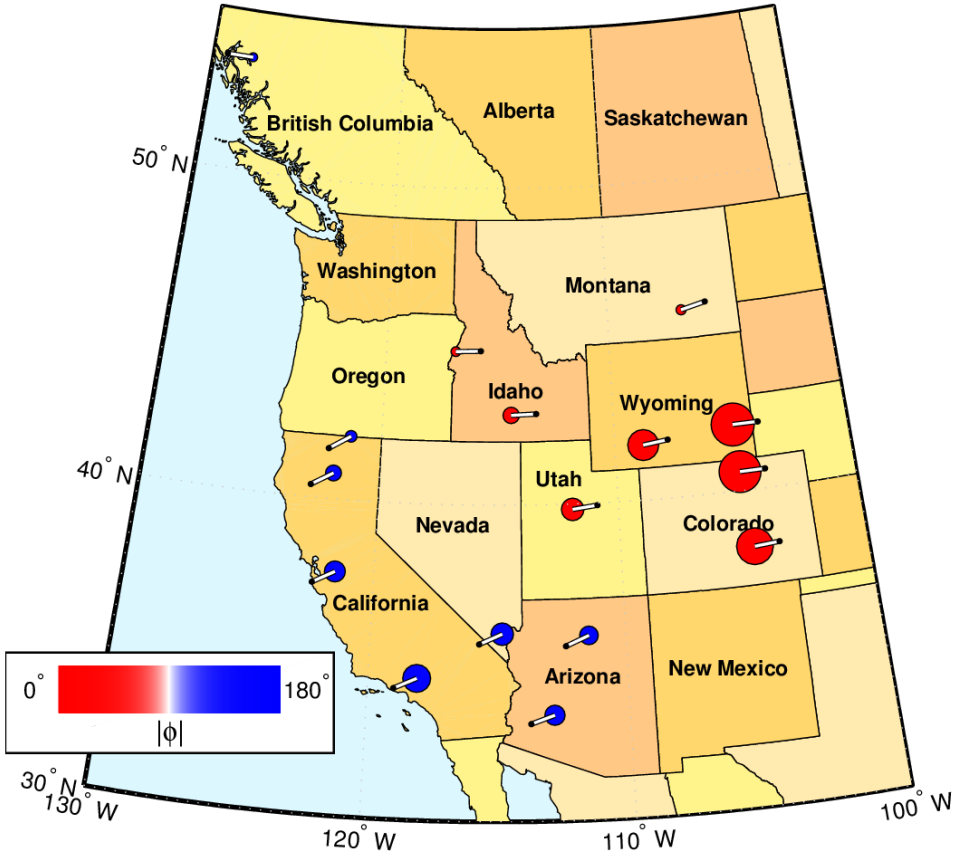
Example: Structured Optimal Control

- Total real power capacity on order of 20 – 50 MW is sufficient
- With 10s of sites deployed, individual resource capacity ≤ 1 MW

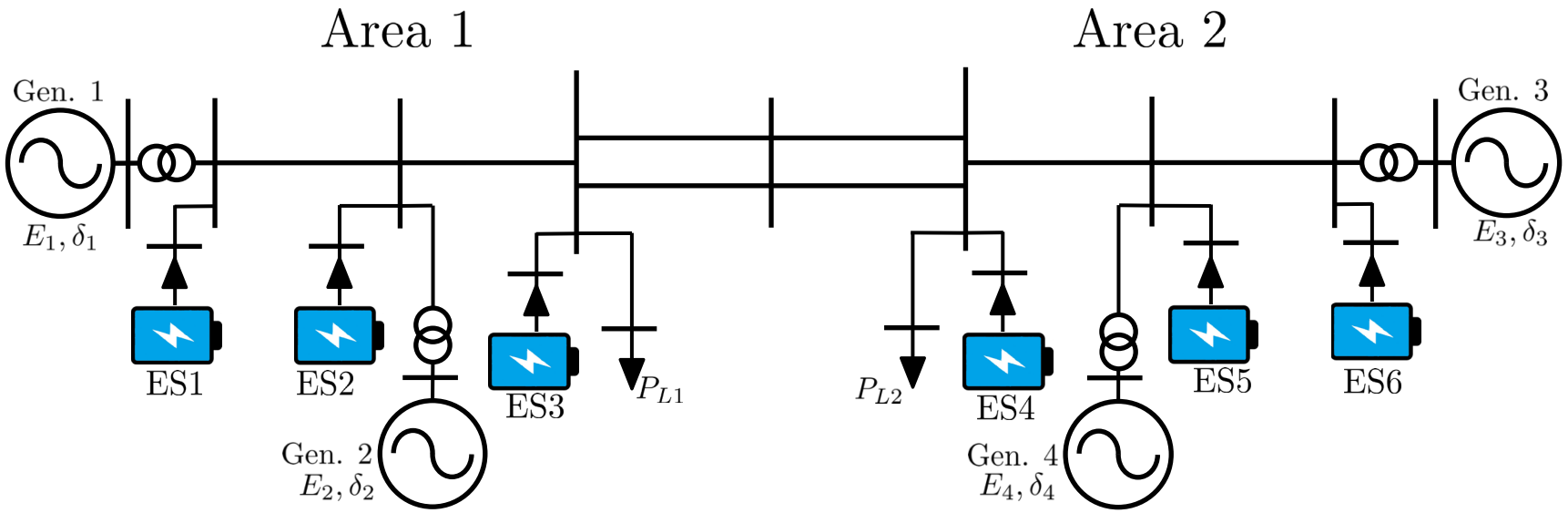




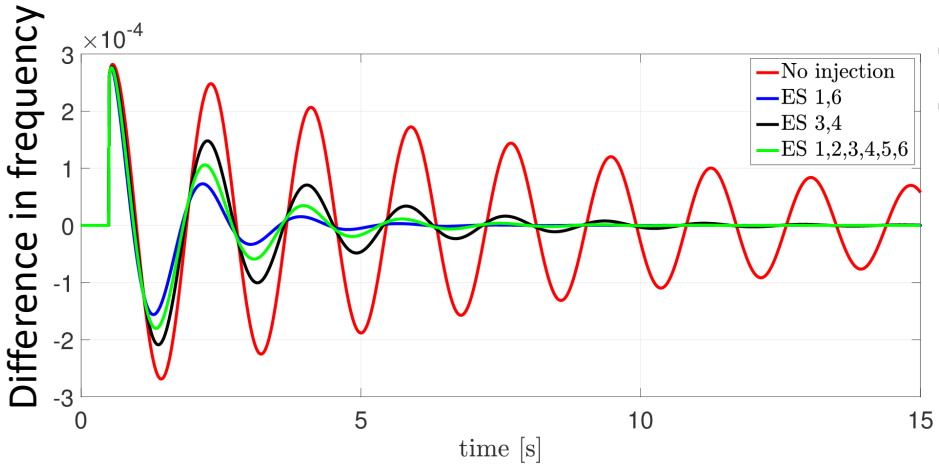
East-West Mode

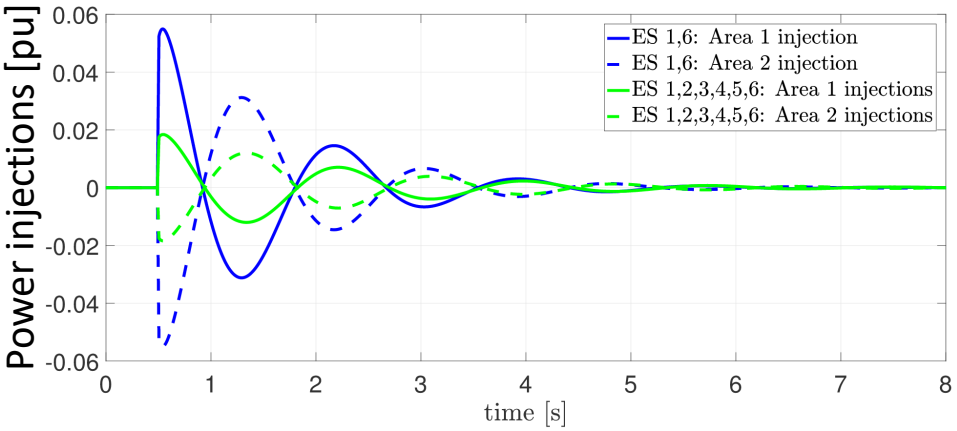


Sizing and Siting Issues



Where to locate the resources, and how large should they be?





Network Considerations

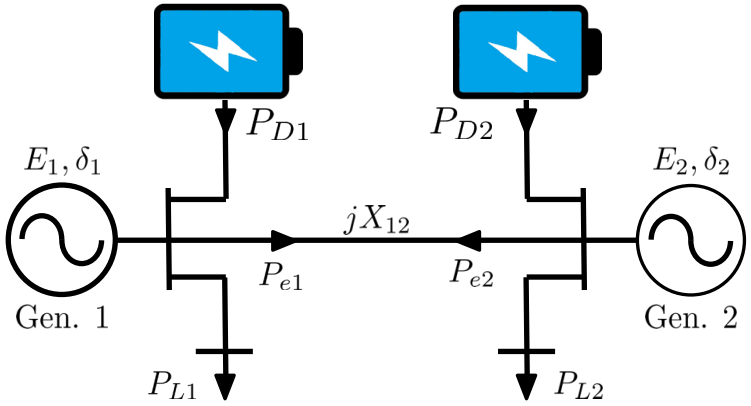
Future implementations will not always be on secure, resilient, efficient networks.

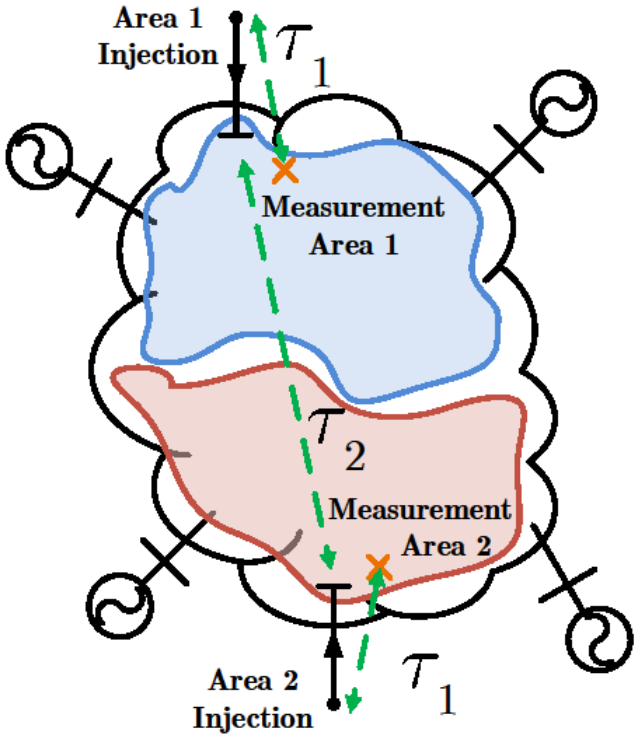
Must accommodate:

- Packet dropouts
- Privacy concerns
- Latency (time delays)

How much delay can the system handle?

How does the distributed control action affect stability in the presence of delays?

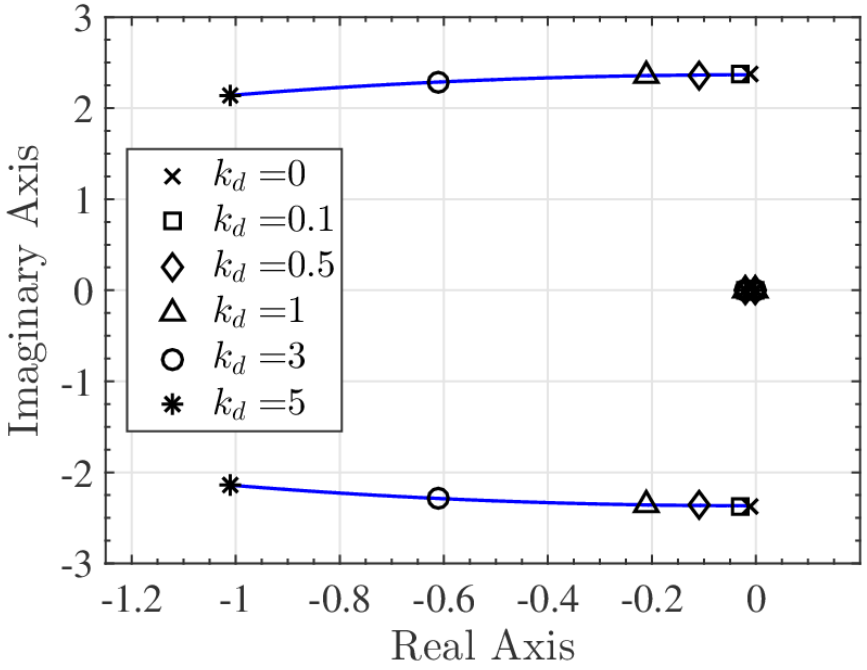




Eigenvalues and Regions of Stability

Eigenvalues

Without delays, increasing damping improves stability (eigenvalues move to the left).

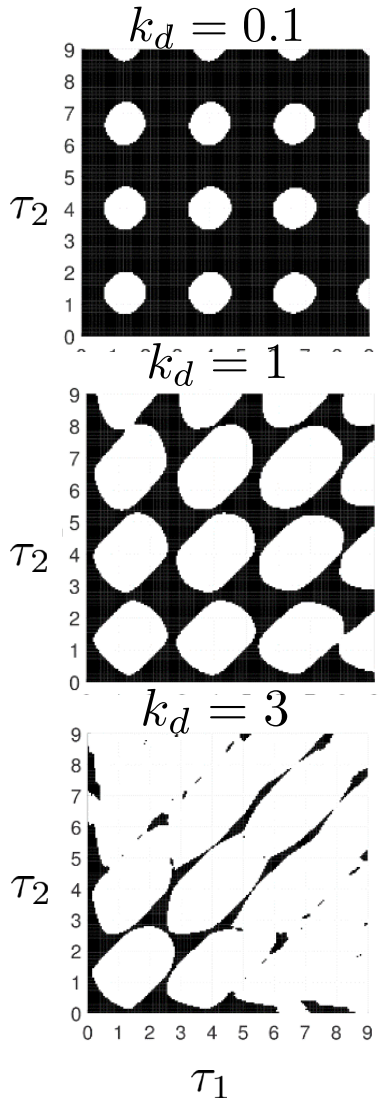


Regions of stability

Black: Stable

White: Unstable

In the presence of delays, increasing control gain may lead to instability.



Conclusions

- Time delays in the feedback signals can cause the damping control to destabilize the system, and stability depends on the size of the delays as well as the size of the control gain.
- Distributed control strategy has minimal impact on SOC of any individual ES site ➔ ES can serve other applications
- Variations in geographic locations of ES can enable control of multiple oscillation modes
- Size of any individual ES is modest when large #'s (10s) of ES are participating in the control strategy
- Preliminary algorithms involving structured optimal control have been simulated with encouraging results
- Small system studies (two area models) have identified key tradeoffs in control system gain vs. measurement data delays

Future Work in Distributed Control Using Energy Storage

- Big data methods to handle thousands of sensor measurements
- Cyber security concerns using network-based approaches.
- Hybrid control strategies that combine distributed ES with other sources of power injection, e.g., PSSs, SVCs, HVDC
- Demonstrations of control strategies

Acknowledgements

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