# BULK POWER SYSTEM SUPPORT BY COLLABORATIVE MICROGRIDS

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#STP069

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## BACKGROUND

Distribution systems containing multiple microgrids with high generating capacity have the potential to increase the overall system resiliency in the face of adverse conditions. To make the most of this potential, robust algorithms are required that can operate with multiple failures within the power or communication infrastructure.

**Main Idea**

This study looks at the specific **objective** of using distribution level microgrids to provide bulk power system (BPS) support in the case that a fault upstream causes a low voltage condition that may result in voltage collapse.

This study considers distributed algorithms:

•Collaborative Autonomy (CA), which uses only peer-to-peer communications and local measurements to determine if a low voltage event is occurring and provide support.

•Average Consensus Algorithm (ACA) which makes use of communication with the distribution management system.

If there are also faults in the local power or communication systems, as may be the case in large scale disaster scenarios, it is desirable to make the best of what is available.

**Research Goals**

•Understand communication requirements for bulk grid support application.

•Understand how these algorithms operate when they are applied to different regions that are not communicating but are supporting the same grid.

## CYBER PHYSICAL TEST SYSTEM

The physical and cyber models are based on a real system with some modifications.

The **physical** power system is modeled in GridLAB-D.

- Bulk power system modeled as Thévenin equivalent
- 3 sub-transmission substations (STS)
- 2 distribution substations (DS)
- 4 feeders
- 2 microgrids

The **cyber** system is modeled in ns-3.

- Fiber-optic communication
- Hierarchical topology
- 5 Agents added to run algorithms
- Distribution Management System (DMS) has access to substation measurements

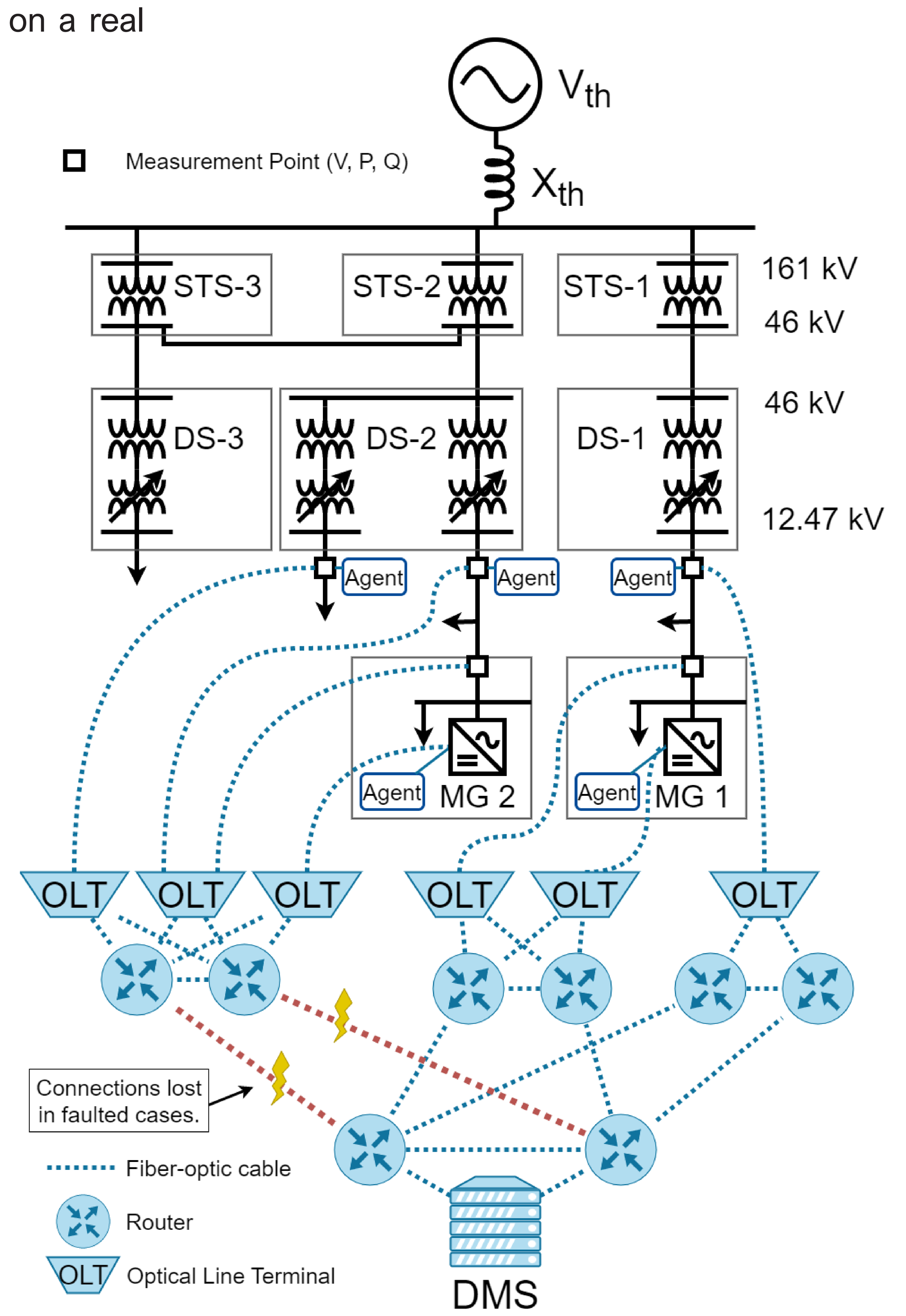


Figure. Cyber-Physical System Diagram.

## ALGORITHMS

Grid support mode is triggered when the voltage of the bulk power system is below a preset threshold (0.95 p.u.). In this mode of operation, the priority is to increase the grid voltage to prevent voltage collapse.

### Collaborative Autonomy (CA)

- Limits single point failures
- Uses only peer-to-peer communication
- Estimates BPS voltage by comparing voltages measured by agents

### Average Consensus Algorithm (ACA)

- Peer-to-peer and hierarchical communication
- The distribution management system (DMS) shares sensitivity (ΔV/ΔQ) and voltage deviation (ΔV)
- Agents share available reserve with peers.

CA DATA FLOW

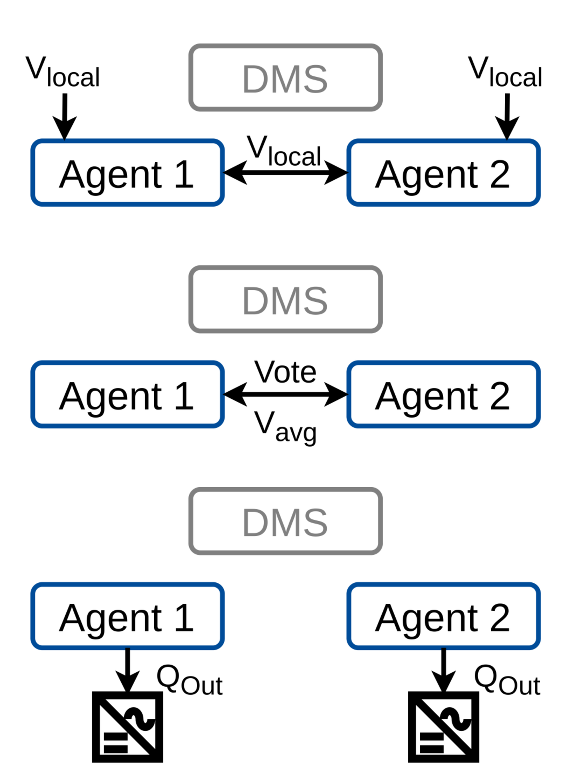


Figure. CA data flow requirements.

ACA DATA FLOW

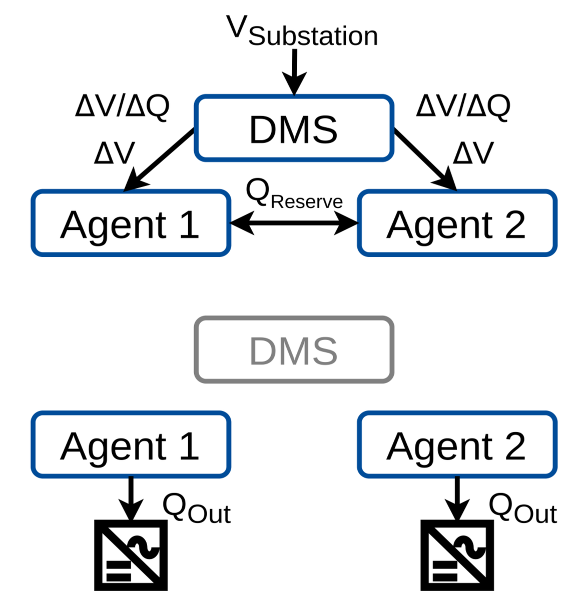


Figure. ACA data flow requirements.

## TEST CASES AND RESULTS

**Model Parameters**

- $V_{th} = 1.035\ pu$
- $X_{th} = \begin{cases} 0\Omega, & t < 5s \\ 290\Omega, & t \geq 5s \end{cases}$
- **Objective:** Achieve BPS Voltage close to 1.0 pu.

**5 Cases with varied algorithms and fault status**

- Intact vs faulted communication system - Communication faults split agents into 2 groups, preventing collaboration between groups

**Case 1:** The two microgrid agents receive the sensitivity and voltage deviation and manage to push the voltage to just below the target by providing the maximum support.

**Case 2:** Since MG-2 is isolated from the DMS it does not provide any support and MG-1 only has the capacity to push the voltage to 0.96 p.u.

**Case 3:** The agents can only estimate the grid voltage by comparing their own local voltages. Using this information, the actual grid voltage gets up to 0.986.

**Case 4:** The 5 agents are split into two isolated groups, and each estimates the grid voltage separately. The result is a slightly lower grid voltage and a less fair distribution of support.

**Case 5:** The three isolated agents use CA and the agents having a connection to the DMS take advantage of their connectivity by using ACA. This case results in the greatest performance under the faulted communications.

TABLE 1. CASES AND RESULTS

| | Algorithms Used | Communication System Status | % MG1 | % MG2 | V (p.u.) |
|---|---|---|---|---|---|
| 1 | ACA | Good | 100% | 100% | 0.996 |
| 2 | ACA/ACA | Fault | 100% | 0% | 0.964 |
| 3 | CA | Good | 83% | 83% | 0.986 |
| 4 | CA/CA | Fault | 59% | 98% | 0.983 |
| 5 | ACA/CA | Fault | 100% | 82% | 0.991 |

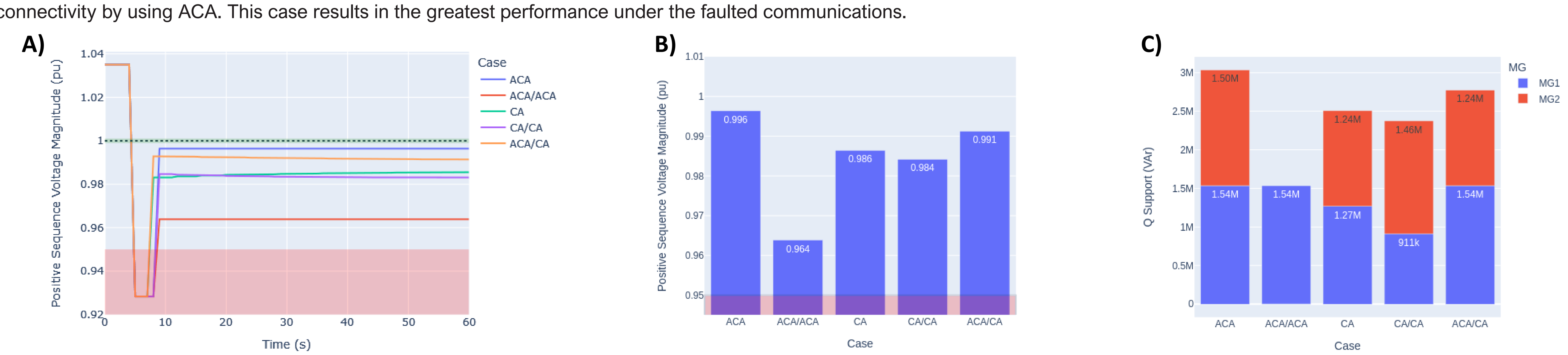


Figure. (A) Time series plot of BPS voltage; (B) Final BPS voltage with support from microgrids; (C) Final reactive power support supplied by microgrids.

## CONCLUSION

This study shows how connected microgrids can be leveraged to improve grid resiliency with varying amounts of information available to the grid edge agents. Even fractured into two regions, the CA algorithm was able to perform well. Greater performance was achieved by taking advantage of DMS connectivity to MG-1 by using ACA in that region.

Systems could be designed to take greater advantage of collaborative autonomy algorithms by adding connections between routers on the edge of the network.

## ACKNOWLEDGEMENTS

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