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## INTRODUCTION

During black start restoration, Mobile Energy Storage Services (MESS) can provide flexible, supplemental energy to black start generators, address significant contingencies, or energize critical loads.

## BLACK START RESTORATION WITH MOBILE ENERGY STORAGE MODEL

### Optimization

**First Stage:** The first stage dictates pre-blackout investments

$$\min \sum_{i \in I} c_i \beta_i$$

**Second Stage:** The second stage sequences energized components jointly with siting and routing MESS, models potential damage scenarios

$$\min E[VOLL] = \sum_{\omega \in \Omega} \rho_{\omega} \sum_{i \in I} \sum_{t \in T} c_i^u u_i^{\omega, t}$$

### Key Constraints

- Component energization sequence
- DCOPTF
- Generator ramping
- MESS discharge and operation
- MESS routing

### Methodology and Assumptions

- 50 or 100 damaging scenarios
- Individual transmission lines damaged with probability  $\rho \in \{.05, .10, .15, .20, .25, .30\}$
- Restoration occurs within a ten hour time period, divided into equally spaced sub periods  $t \in \{10, 20, 30, 40, 50\}$

### Test Case

- Standard IEEE 14-bus instance
- Results analyzed from two major perspectives:
  - system load shed during black start restoration,
  - location and discharge of the MESS throughout the black start process

#### Case 1

Generation only

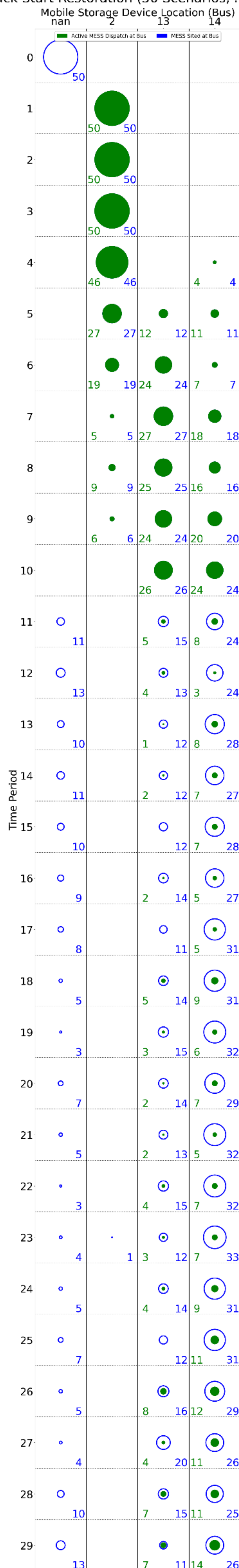
#### Case 2

Generation and static storage

#### Case 3

Generation and mobile storage

Mobile Energy Storage Siting and Discharge During Black Start Restoration (50 Scenarios, .05 Failure Rate)



## MOBILE ENERGY STORAGE SITING ANALYSIS

- Clear optimal location to initially site MESS; then scenario-based weighting for subsequent sites. Movement throughout restoration is always optimal.
- Higher temporal resolution modeling leads to more variation in optimal siting and results in more frequent situations of MESS sited at a location but not actively discharging

## LOAD SHED RESULTS

System-wide Loadshed During Black Start Restoration (100 Scenarios, .05 Failure Rate)

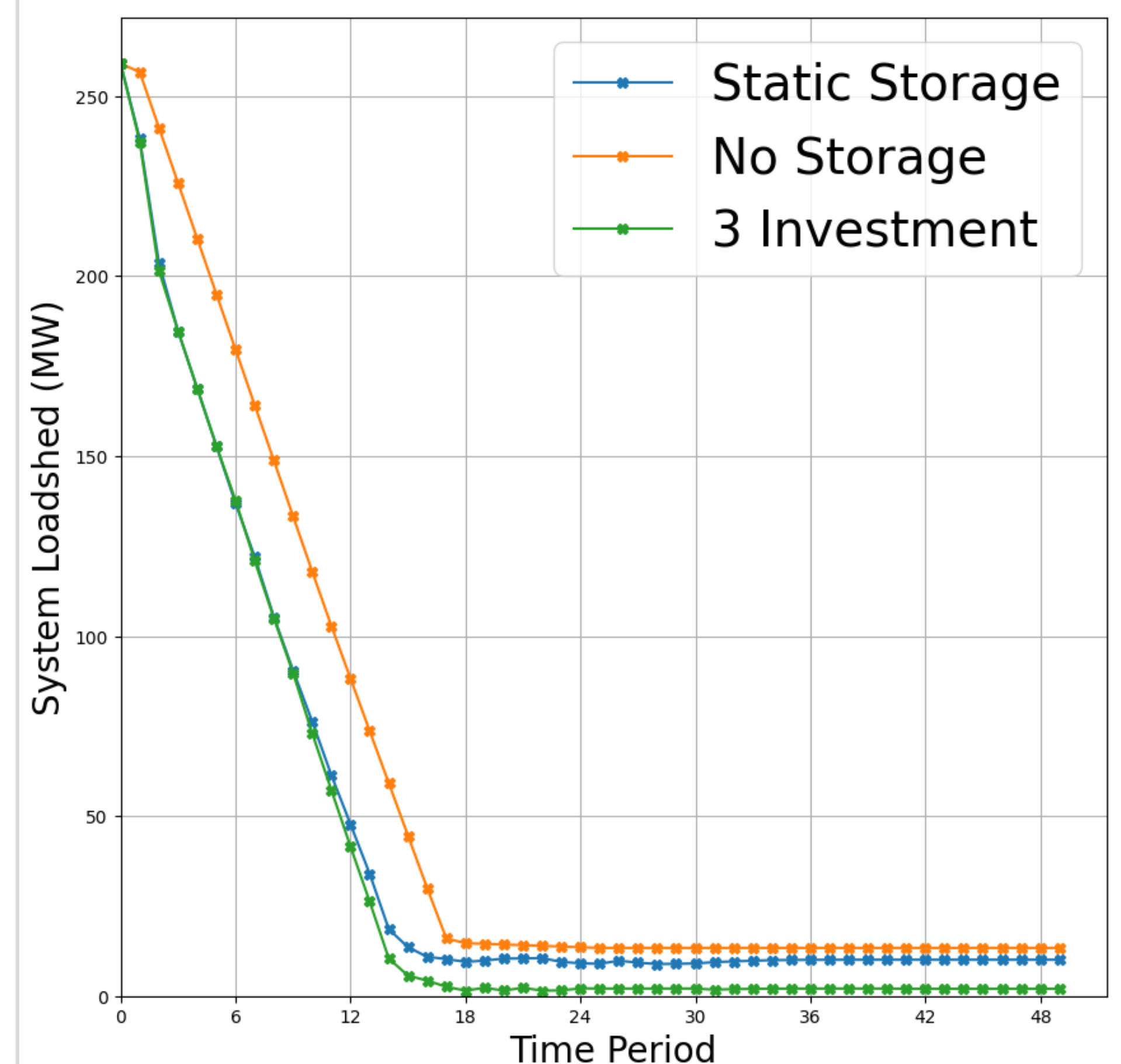


Fig: Average System Load Shed for High Damage Scenarios

## CONCLUSION

### MESS Accelerate Black Start Restoration

Investing in storage (static or mobile) can accelerate the black start restoration process, especially in instances of significant system damage.

### MESS > Static Storage

The use of a mobile energy storage can be more effective than a static storage device in quickly reducing system load shed and keeping it low.

### Mobility is Valuable

The mobility of mobile energy storage devices is valuable for restoring overall load during the black start restoration process, especially in higher damage scenarios.