

CHAPTER VI

CONCLUSION

This research developed and validated a comprehensive framework to enhance voltage stability in distribution networks with high renewable energy penetration. It began by refining the L-index method to efficiently identify weak buses prone to voltage instability, which helped guide the strategic placement of BESS.

Next, an adaptive voltage-droop control scheme was designed for BESS, where the droop parameters dynamically adjust based on the battery's SoC. Using PSO, the controller reduced voltage deviation and significantly cut power oscillations in the batteries.

To ensure long-term battery health alongside grid support, a FMOO layer was incorporated. This balanced minimizing voltage deviations with restoring SoC, successfully keeping battery charge within initial levels while voltage profiles improved when compared to only renewable energy.

While the study focused on steady-state analysis and used simplified battery aging models, it showed practical benefits by targeting only critical buses, avoiding unnecessary BESS deployment, and enabling implementation on commercial power converters.

In conclusion, this research demonstrates that integrating L-index-based siting, PSO-optimized adaptive droop control, and SoC-aware multi-objective dispatch provides an effective and practical solution to voltage stability challenges in renewable-rich distribution systems.

A key practical application of this integrated framework lies in its direct applicability to the day-ahead operational planning of BESS, transforming grid management from a purely reactive to a proactive and predictive model. By utilizing

day-ahead forecasts for renewable generation and load demand, grid operators can employ the developed tools to formulate an optimized 24-hour operational schedule. In essence, this work provides not just a solution for voltage stability, but a comprehensive scheduling methodology that enhances grid reliability while ensuring the operational and economic viability of energy storage assets in modern power systems.