Optimization of Power Stability Index in Presence of Large-scale Integration of Green Power Generation

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INTRODUCTION & AIM

The rapid growth in global electricity demand, combined with environmental concerns, has promoted the large-scale integration of renewable energy sources into modern power systems. Although wind and photovoltaic generation significantly contribute to reducing greenhouse gas emissions, their integration through power electronic interfaces reduces system inertia, making power systems more vulnerable to frequency variations and instabilities, particularly in low-inertia networks. Consequently, analyzing the impact of renewable energy sources on key stability indicators—such as frequency nadir, RoCoF, frequency response time, and machine angular synchronization—is essential for the design and operation of future power systems. Enhancing the stability of power networks with high renewable energy penetration requires robust control strategies based on artificial intelligence and nature-inspired optimization algorithms. The objective of this paper is to provide clarification on the main stability indices used to assess renewable energy integration. To this end, the Power System Analysis Toolbox (PSAT) in MATLAB was employed. The IEEE 39-bus system was used as the study model, to which renewable energy sources are added. The system was modeled using well-tested components documented in IEEE and WECC standards.

METHOD

The case study presented in this work focuses on the IEEE 39-bus power system. The system comprises 46 transmission lines, 39 buses, 10 synchronous generators, 10 synchronous compensators, and 19 load buses, as shown in Fig 1.
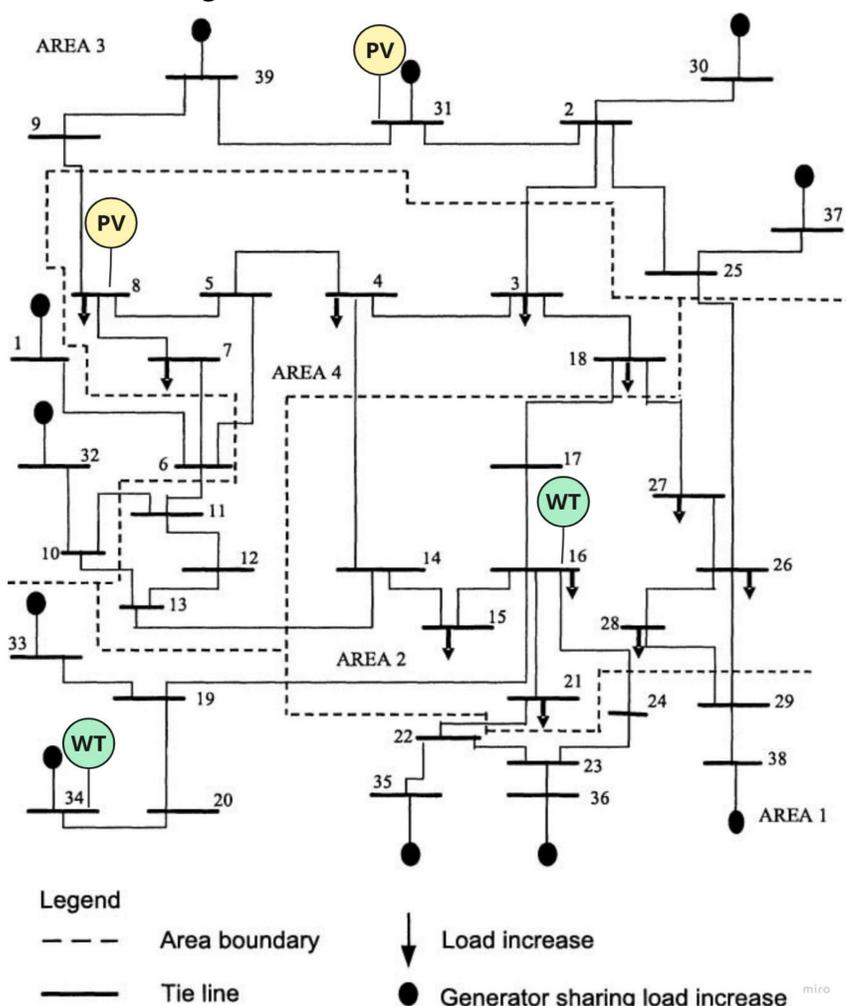

Figure 1 : WSCC-IEEE 39 bus power system Model

RESULTS & DISCUSSION

For system simulation, the Power System Analysis Toolbox (PSAT) under MATLAB was used. Wind turbines and photovoltaic generators were integrated at generation and load buses. The system was simulated under both stable and unstable operating scenarios. The dynamic stability analysis is based on two main stability indices: the critical clearing time (CCT) and the rate of change of frequency (RoCoF). The investigated disturbances include a three-phase short circuit at a network bus and a generator tripping event. These disturbances were selected to represent the most severe operating scenarios. It can be noticd that optimizing the stability index can enhance dynamic behaviour of the system in presence of load changes and renewable sources.
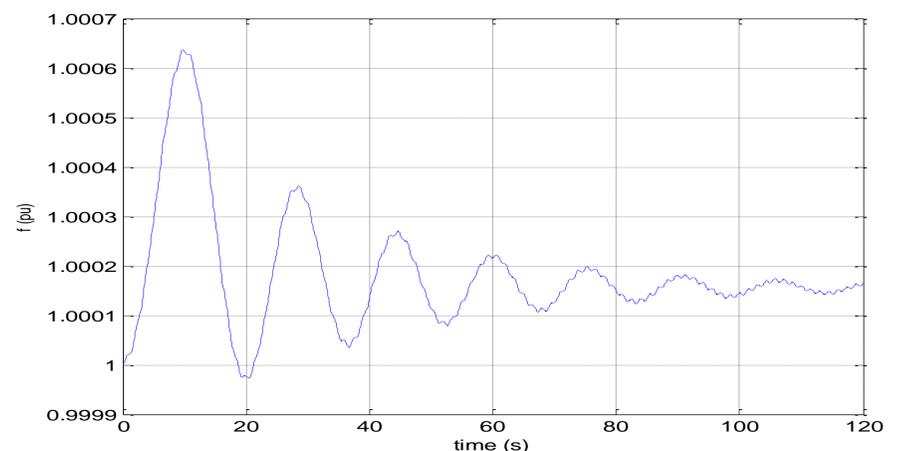

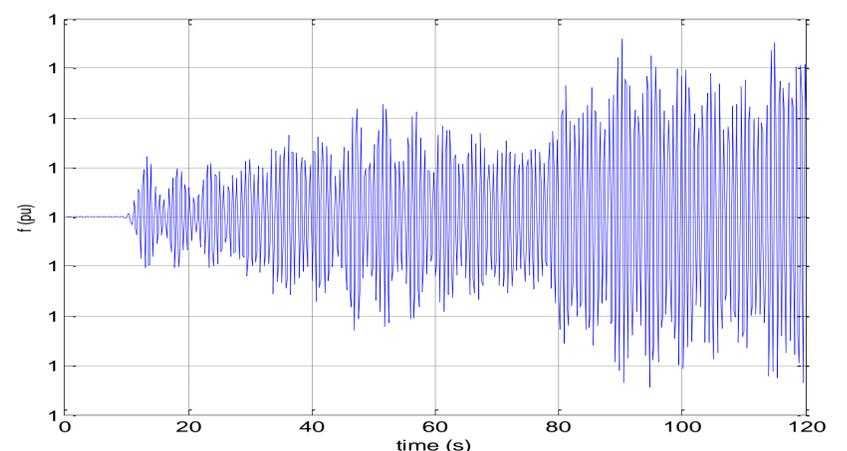**Figure 2 . system Frequency with Load Variation.**

Figure 3 . System Frequency with RES.

CONCLUSION

This study analyzes the criteria and methodologies used by network operators to determine the maximum level of renewable energy integration in power systems, based on performance criteria and stability indices, with particular emphasis on system robustness and inertia. It can therefore be stated that the integration of renewable energy sources at different locations in the network, with varying active power penetration levels, influences stability indices (CCT and ROCOF) and, consequently, the dynamic stability of power systems.

FUTURE WORK / REFERENCES

[1] Saleem, M., Saha, S., Roy, T., Ghosh, S.K., 2024. Assessment and management of frequency stability in low inertia renewable energy rich power grids (Apr). IET Gener., Transm. Distrib. 18 (7), 1372–1390.

[2] A Brik, NEY Kouba, AA Ladjici, Optimal Sizing and Placement of Renewable Energy Sources in Power System Connected Multi-Microgrids, Journal of Renewable Energies, 2025.