Abstract of the Thesis

Name: SARIKA SANJAY KANOJIA
Enrollment No.: 189999914015
Faculty: 1) Dr. Bhavik N. Suthar (Supervisor)
2) Dr. Ashutosh K. Giri (Co-Supervisor)
Discipline/Branch: ELECTRICAL ENGINEERING
Title of the Thesis: VOLTAGE STABILITY INVESTIGATION IN MODERN POWER SYSTEM

Abstract

The rapid growth of Electric Vehicle Charging Stations (EVCS) and the increasing penetration of renewable energy-based Distributed Generation (DG) have significantly influenced the planning and operation of modern electrical distribution networks. Although the integration of EVCS, solar photovoltaic (PV), and wind-based generation offers substantial environmental and operational benefits, their uncoordinated deployment may result in voltage instability, increased power losses, network congestion, and deterioration of power quality. Therefore, effective planning, optimal resource allocation, and robust grid-integration control are essential to ensure the reliable and secure operation of distribution systems. In this context, the present research develops an integrated optimization and control framework for enhancing voltage stability, reducing network losses, and improving power quality in EV-integrated renewable distribution networks.

Initially, a hybrid Coati Optimization Algorithm and Pelican Optimization Algorithm (COA-POA) is developed for the optimal placement of EVCS in distribution networks. The optimization framework considers voltage deviation and voltage stability as key performance objectives, thereby identifying suitable EVCS locations while minimizing their adverse impact on network operation. The complementary exploration and exploitation characteristics of COA and POA enhance the search capability of the hybrid approach and improve the quality of the obtained solution. Voltage Stability Index (VSI) is used to identify weak buses and critical sections of the network under increased EV charging demand.

To provide local generation support for the additional EV charging load, solar PV and wind-based DG units are subsequently integrated into the distribution network. Their optimal placement is determined using the World Cup Optimization (WCO) technique. A multi-objective voltage stability assessment incorporating the Fast Voltage Stability Index (FVSI), Line Stability Index (LSI), and Line Stability Factor (LSF) is employed to comprehensively evaluate network stability. The proposed WCO-based framework identifies suitable DG locations while improving the voltage profile, reducing active power losses, and enhancing voltage stability margins. The proposed optimization methodologies are validated using IEEE 33-bus and IEEE 69-bus radial distribution systems through MATLAB/Simulink simulations. Comparative evaluation with established optimization techniques demonstrates the effectiveness and competitive performance of the proposed approaches.

Head office : GTU Campus, Nr. Visat Three Road , Visat-Gandhinagar Road , Chandkheda, Ahmedabad - 382 424. Gujarat, India.
Phone .:- +91 079-23267521/570 e-mail : info@gtu.ac.in Website : www.gtu.ac.in

In addition to optimal network planning, the research addresses power quality and grid-synchronization challenges associated with grid-connected renewable energy systems. A Complex Band-Pass Filter based Frequency Locked Loop (CBF-FLL) controller is developed for a dual-stage grid-connected solar PV system. The proposed controller enables accurate estimation of the fundamental frequency and phase under distorted, unbalanced, and weak-grid conditions, while supporting effective voltage regulation and harmonic mitigation at the Point of Common Coupling (PCC). Its performance is evaluated under variable solar irradiance, dynamic and unbalanced loads, distorted grid voltage, and weak-grid operating conditions. The simulation results demonstrate accurate grid synchronization, improved transient response, effective DC-link voltage regulation, and reduced harmonic distortion within the permissible limits of IEEE 519.

Overall, the research presents an integrated framework for optimal EVCS placement, renewable DG allocation, voltage stability assessment, and advanced grid-interfacing control. The COA-POA approach supports effective EVCS planning, WCO-based DG allocation improves voltage stability and reduces losses, while the CBF-FLL controller enhances synchronization and power quality. Collectively, these methodologies support improved voltage stability, reduced losses and harmonics, enhanced renewable energy integration, and reliable operation of modern distribution networks.

This PhD Thesis would be useful for electric utilities, power system industries, renewable energy developers, EV charging infrastructure providers, and researchers in planning and operating reliable, energy-efficient, and sustainable distribution networks. The proposed methodologies can support utilities and industries in the optimal placement of EV charging stations and renewable distributed generation, voltage stability enhancement, power-loss reduction, and improved power quality. The outcomes can also assist in the development of smart grids and sustainable EV charging infrastructure by enabling better integration of solar and wind energy with existing distribution networks. Furthermore, the proposed CBF-FLL control strategy can be useful for improving grid synchronization and power quality in grid-connected renewable energy systems.

List of Publication(s):

(1) Kanojia, Sarika S., and Bhavik N. Suthar. “Voltage stability index: a review based on analytical method, formulation and comparison in renewable dominated power system.” *International Journal of Applied power Engineering* 13.2 (2024): 508-520. DOI: 10.11591/ijape (*Scopus indexed journal*).
(2) Kanojia, Sarika S., Suthar, B.N. & Giri, A.K. “Hybrid Optimization Approach for Optimal Location of Electric Vehicle Charging Station (EVCS) in Distribution Network Considering Voltage Stability”. *Smart Grids and Sustainable Energy* 10, 36 (2025). https://doi.org/10.1007/s40866-025-00264-2. IF-1.9. (*ESCI -Web of Science and Scopus indexed journal*).
(3) Kanojia, Sarika S., Bhavik N. Suthar, and Ashutosh K. Giri. “Voltage Stability Enhancement by Optimally Placing DG in radial distribution network: A comparative analysis" Journal of The Institution of Engineers (India): Series B (IEIB), volume 107, pages 1341-1356 (2026). https://doi.org/10.1007/s40031-026-01315-7. Springer nature. *(SCOPUS indexed journal*).
(4) Kanojia, Sarika S., Bhavik N. Suthar, and Ashutosh K. Giri, “DG Placement for Enhanced Voltage Stability in EVCS Integrated Network”. International Journal of Engineering Research and Applications. ISSN: 2248-9622, Vol. 16, Issue 8, August 2026, pp 65-73 DOI:10.9790/9622-1608657365. (*UGC approved*).