INFORMATION ABOUT RESEARCH RESULTS

Thesis title: **Optimal balanced and unbanlanced three-phase distribution systems with distributed generators**

Major: Electrical Engineering Code: 9520201

PhD candidate: Pham Dinh Thai Course: 2021

Academic supervisors:

Dr. Nguyen Trung Thang

Assoc. Prof. Dr. Le Chi Kien

Training institution: Ho Chi Minh City University of Technology and Education

1. Summary of content

In the context of the gradual depletion of fossil fuel sources and increasing concerns about environmental issues, the use of renewable energy sources such as solar power and wind power is considered a viable alternative solution. These sources offer many advantages such as reducing power losses, improving voltage profiles, enhancing system reliability, and minimizing operating costs. However, determining the optimal location and capacity of these renewables in the power grid, especially at the distribution level is a complex problem that requires consideration of all economic, technical, and environmental aspects. Therefore, this thesis focuses on addressing the problem of optimal installation for distributed generators such as photovoltaic sources (PFs), wind turbines (WFs), capacitor banks (CB), and battery energy storage systems (BESS) in distribution networks to maximize economic benefits while satisfying all technical criteria.

This thesis has successfully implemented and developed a method that combines optimization algorithm with simulation software to determine the control variables related to the placement and sizing of distributed generators in distribution networks. The Modified Coyote Optimization Algorithm (MCOA) is proposed to aaply as an effective optimization algorithm for solving various types of real-world distribution networks, including:

- Balanced three-phase distribution girds: Systems which have load power at each phase is equal.
- Unbalanced three-phase distribution girds: Systems which have load power differ between phases and the number of phases may also vary.

In this study, three typical problems are considered. The first problem involves applying MCOA to identify the placement and sizing of PFs, WFs, CBs, and BESS in the balanced three-phase system considering time-varying loads and grid-connected units. The second problem finds the optimal solution for the penetration of PFs and WFs into unbalanced distribution networks due to imbalanced loads. The third problem addresses optimization problem for connection of PFs, WFs, and BESS in the large-scale and complex of unbalanced three-phase distribution networks with many existing devices. The second and third problems apply Beta and Rayleigh probability distribution functions to simulate solar radiation and wind speed, thereby predicting power output from photovoltaic modules and wind turbines, respectively.

Additionally, the research also proposes a co-simulation tool by using two open-source software of OpenDSS and MATLAB via the COM interface to solve optimization problems efficiently and conveniently. The obtained results from applying the proposed optimization solution for installating distributed units in the distribution networks show significant benefits, including decreased investment and operational costs, reduced branch power losses, improved voltage profile, and enhanced system reliability. Furthermore, the research demonstrates the superiority of the proposed algorithm (MCOA) compared to other optimization algorithms such as IPSO (Improved Particle Swarm Optimization), CSA (Cuckoo Search Algorithm), SSA (Salp Swarm Algorithm), SMA (Slime Mould Algorithm), and COA (Coyote Optimization Algorithm) under similar objectives and constraints. This provides practical value in identifying effective method and tool for solving various optimization problems.

2. New contributions of the research

The new contributions of the thesis can be briefly summarized as follows:

- The thesis successfully determines the optimal connection solution of solar and wind power sources, capacitor banks, and energy storage systems with the goal of minimizing total cost while still meeting all technical criteria. The total cost considered includes: (1) investment cost, (2) operation and maintenance cost, (3) power generation cost from the main grid, and (4) emission cost from conventional power plants. This is evaluated as a comprehensive consideration for the problem of determining the optimal penetration solution of distributed sources into the distribution grid.
- Harmonic distortion caused by nonlinear loads and power conversion devices on the power grid is taken into account. These harmonics negatively impact the grid and must comply with IEEE Std. 519 and 30/2019/TT-BCT. This has hardly received adequate attention from previous studies around the world.
- The thesis has successfully developed a novel optimization algorithm with the high stability, called MCOA, which aids in identifying optimal location and capacity of distributed generators in different types of distribution networks. Additionally, the research successfully implements a co-simulation between MATLAB and OpenDSS. This co-simulation offers many advantages in terms of flexibility and processing speed when performing power flow calculations and solving complex optimization problems.
- The this has also conducted mathematical models for various types of balanced and unbalanced three-phase distribution networks to assess the impact and effectiveness of distributed generation systems.

Ho Chi Minh City, 24/ 07/ 2025

PhD candidate

Pham Dinh Thai