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Review on Load Flow Analysis and Power Loss Minimization in 33 Bus Power Distribution System

Sanjay Bhuriya, Assistant Professor Raghunandan Singh Baghel
School of Engineering &Technology, Vikram University Ujjain, Department Electrical Engineering

Abstract- In the literature, there are a number of efficient and reliable load-flow solution techniques, such as: Newton-Raphson method, Fast Decoupled Load flow method and Gauss-Seidel method. These techniques are well valid for transmission systems. The distribution systems are radial in nature (practically weakly meshed) whereas transmission systems are loop in nature. The distribution networks have a high R/X ratio compared to the transmission networks and hence are ill-conditioned in nature.

Index Terms- Load-flow methods, Distribution networks, R/X ratio.

I. INTRODUCTION

Besides giving real and reactive power the load flow study provides information about line and transformer loading (as well as losses) throughout the system and voltages at different points in the system for evaluation and regulation of the performance of the power systems. Further study and analysis of future expansion, stability and reliability of the power system network can be easily analyzed through this study. Growing demand of the power and complexity of the power system network, power system study is an significant tool for an power system operator in order to take corrective actions in time. The advent of digital computers, load-flow solutions were obtained using network analyzers.

The first practical automatic digital solution method appeared in the literature in 1956. The popular traditional 'Gauss-Siedel' iterative method which require minimal computer storage through Y-matrix. Although the performance is satisfactory on different systems but the main drawback is its converging time. To overcome this deficiency led to the development of Zmatrix methods, which converge more reliably but sacrifice some of the advantages of Y-matrix iterative methods, notably storage and speed when applied to large systems. The other conventional methods like Newton-Raphson method was shown to have powerful convergence properties, but was computationally uncompetitive. Major breakthrough in power system network computation came in the mid-l960. Development ordered elimination [1] and after that it leads in to a preeminent general-purpose load-flow approach which has been adopted by much of industry Currently, with the stimulus of increasing problem sizes, online applications, and system optimization, newer methods are emerging which are also expected to find wide applications. The brief explanation of basic formulation of the load-flow problem is described in [2]-[4]. For review, a balanced three phase power system along with transmission line has been considered.

II. LOAD FLOW ANALYSIS

Load flow analysis, also known as power flow analysis, is a fundamental tool used in electrical engineering, specifically in the planning and operation of power systems. It is a numerical analysis conducted to determine the steady-state distribution of electrical power flow through a network under a given load condition. The analysis provides critical information on the voltage at each bus (node) in the system, the real and reactive power flowing through each branch (transmission line or transformer), and the power generated and consumed at different points in the network.

1. Purpose and Applications

- Load flow analysis is essential for:
- Designing and planning new electrical power systems or expanding existing ones.
- Optimizing the operation of power systems for efficiency and reliability.
- Determining the capacity utilization of different components in the system, identifying bottlenecks, and planning necessary upgrades.
- Assessing system behavior under various load conditions.
- Voltage profile analysis across the network to ensure voltages remain within acceptable limits.
- Planning reactive power compensation and voltage control strategies.

2. Key Parameters and Outputs

The primary inputs for a load flow study include:

- The network topology, detailing how different buses (nodes) are connected by branches (lines and transformers).
- The electrical characteristics of all components, including line impedances and transformer parameters.

- The generation (power output and voltage set points of generators) and load data (real and reactive power demands).
- The main outputs from a load flow analysis are:
- Voltages at each bus in the system, both in magnitude and phase angle.
- Power flows (real and reactive) on each branch.
- The real and reactive power generated at each generator.
- Losses in the system.

III. METHODS

Several computational methods can be used for load flow analysis, including:

1. Newton-Raphson Method
A highly efficient iterative method known for its fast convergence, especially suitable for large and complex systems.

2. Gauss-Seidel Method
An older iterative method that is simpler but generally slower and less robust than the Newton-Raphson method.

3. Fast Decoupled Load Flow
A variation of the Newton-Raphson method that decouples real and reactive power calculations to speed up the computation.
Importance

Load flow analysis is critical for the reliable, efficient, and safe operation of power systems. It helps engineers and system operators make informed decisions about system design, operation, and expansion, ensuring that the power supply meets demand under various conditions while maintaining system stability and quality of service.

IV. LITERATURE REVIEW

Nisa Nacar Cikan et al. Reconfiguration is an efficient solution for loss minimization and system improvement in the power distribution network (PDN). Although reconfiguration has been studied for a long time, most works to date approach the problem considering the system balanced with constant PQ-load, while real PDNs are unbalanced due to uneven loads. On the other hand, unbalanced loadings can lead to increased energy losses, violate capacity limits, and affect power quality, resulting in voltage and current unbalance (CVU). Therefore, methods that mitigate the adverse effects of CVU are necessary. In this paper, the slime mould algorithm (SMA) is used to solve the reconfiguration problem (RecPrb) in a 123-bus unbalanced system with the objectives of minimization of power loss, the current unbalance index (CUI), and voltage unbalance index (VUI). The system is evaluated in two parts by considering many cases where power losses and unbalanced indexes are gradually minimized with the presented scenarios. A three-phase unbalanced backward-forward-load-flow Matlab script is written, and all simulations are run in the Matlab environment. The test system is built in Open DSS and Matlab/Simulink to verify the script's correctness, and the obtained results are also validated with the IEEE-PES data. The effectiveness of the SMA method is further assessed by comparing it with well-known EO and DE algorithms using over 15 statistical methods to find the most efficient algorithm that solves the Rec Prbs of unbalanced test systems. The results demonstrate the robustness and efficiency of the SMA method in minimizing losses, limiting unbalanced indexes, and improving the system's voltage profile.

Abdulwasa Bakr Barnaw et al. Economic growth, population rise, and industrialization have increased the daily energy demand. The rapid depletion of fossil fuels and the adverse effects of greenhouse gas (CO2, NOx) emissions from huge conventional power plants, forced the environmentalists and power system engineers to come up with an alternative solution for more reliable and economical generation and distribution of electricity. The alternating current optimal power flow (AC-OPF) problem is an effective tool for analysis, which involves the adjustment of certain controllable variables to optimize objective functions while satisfying operational, physical, and security limits on various controls and dependent variables. This paper focuses on analyzing the optimal power flow operation of a system with renewable integration, taking into account more popular wind and solar resources along with electric vehicles and tidal energy systems. In this context, proposed a model of the optimal power flow problem incorporating thermal-hydro-solar-wind-tidal-EV energy systems. Probability distribution functions (Weibull, Gumbel, and Lognormal) are used for renewable uncertainties and to determine predictable wind and solar power for proper generation scheduling. Furthermore, this paper provides solutions to the optimal power flow problem by including test cases of stochastic renewables involving minimizing the cost of power generation, minimizing emissions from fossil-fuelled plants, minimizing losses in the system, maximizing profit, and maximizing voltage stability. The generalized normal distribution optimization algorithm is applied to handle the above-mentioned AC-OPF problems in contingency conditions. The proposed method is employed on a modified IEEE 30-bus system integrated with RESs to assess the accuracy and performance. Statistical analysis and comparison of the results establish the superiority and robustness of the proposed algorithm over other available techniques in the literature. Simulation solutions indicate that the recommended optimization can achieve reasonable techno-economic results. Such optimum performance is expected to increase the power systems towards net zero and use renewable energy sources.

Mohamed Bahloul et al. This study proposes a statistical analytic method for collocating a PV power plant and utilityscale energy storage system (UESS) to minimise clipping losses. The novelty of this approach is to assist the PVPP operator in estimating the clipped energy in case of scaling up/down the PVPP generation and/or inverter conversion capacity. Moreover, a detailed economic model is presented to analyse the viability of the UESS and identify the most appropriate technology, storage capacity, and power budgets among the available ones in the market. As a real-life example, the 5-MW Kelmoney PVPP in Ireland has been considered for this analysis. Different case studies have been presented considering different inverter loading ratio (ILR) indices and design scenarios. Results show that the financial viability of UESS deployment for PV clipping losses minimisation as a unique service is a conservative option. The increase in the ILR value of the installation and the development of energy storage technologies greatly impact the UESS sizing and will play a potential role in improving the economic sustainability for clipping losses minimisation application for UESS. Meanwhile, it is suggested combining this service within a multi-service provision framework to achieve a profitable operation.

Aliva Routray et al. DG technology has always been an interface for improving power efficiency and power quality in distribution system. The objective of the work is to minimize the distribution system line losses with wind energy as DG. A wind farm is formed with irregularly placed wind turbines to generate maximum energy with minimum wake loss caused by single wake as well as multi wake effect. The wake losses are analyzed with varying inter turbine horizontal distance for the same wind farm. A new reconfigured wind farm is designed which minimizes the wake loss due to wake effect on downstream turbines and enhances the power generation from the wind farm. This paper presents the complete analysis of wake losses caused to each individual turbine. The hourly wind speed data is generated from previously available thousands of wind speed data using Kernel Density Estimation (KDE). Load Impedance Matrix (LIM) based Distribution System Load Flow (DSLF) method is implemented to find the power losses and bus voltages in the system. For the study, effect of air density on wind, wake effect on wind and hourly load variation are considered. Two standard test cases, IEEE-28 and IEEE-69 bus Radial Distribution System (RDS) are considered for the optimal DG placement. The optimal location of DG is found out using Grey Wolf Optimization (GWO) Technique.

Yinpeng Qu et al. The loss minimization has been an important optimization problem in distribution systems because of the economic incentives. The state-of-the-art feeder reconfiguration for minimizing unbalanced distribution systems' losses cannot prove the optimality of solutions mathematically due to the non-convexity of the problem. This paper proposes a global optimal flow pattern of feeder reconfiguration to provide a best start point and convergence direction for search strategies. The global optimality and the uniqueness of the global optimal flow pattern are proved. Therefore, the loss of the global optimal flow pattern is the lower bound of the feeder reconfiguration for loss minimization. Two global optimal flow pattern-based search strategies are developed to find the global or near optimal solutions. The performance of the proposed algorithms is validated with three test systems for different application scenarios. Test results demonstrate that the efficiency of the search strategies is greatly improved by the global optimal flow pattern and the optimality of solutions can be verified.

V. CONCLUSION

This paper gives a brief overview of various methods for distribution system load flow analysis, including deterministic and probabilistic methods. The system where there is uncertainty in the line and load data is not suitable for the deterministic approach. Sincere attempts were undertaken in this article to take the uncertainty in the load data into account, and a modified algorithm based on B/F sweep was evaluated on an IEEE-33 Bus system. The findings demonstrate how uncertainty impacts the system's voltage profile, losses, and loading.

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