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Recent Review On Load/power Flow Analysis

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Abstract—**This paper presents the latest review of power/load flow analysis methods from recent published work. These methods are grouped into conventional (Gauss-Siedel, Newton Raphson, Decoupled, and Fast Decoupled), and non-conventional (Fuzzy Logic, Artificial Neural Network, and Other Miscellaneous Methods). This work shows a summary of the latest works in this research topic. This give researchers insight into the available information on the current methods of load/power flow. It also enable researchers to possibly compare all the methods, as well as improve on the existing methods.**

Keywords— Y-matrix, Z-matrix, Load Flow, Fuzzy Logic, and Artificial Neural Network.

1 Introduction

Load flow study provides information on real and reactive power, 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. Power flow analysis needs to meet the contemporary demand for power system operation and planning. The contemporary demands influenced many researchers to spell out on the load flow analysis [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29]. The methods employed for load flow analysis can be grouped into; conventional methods such as Gauss-Siedel and Newton-Raphson [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], and non-conventional methods, such as fussy logic and artificial [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29]. Some researchers proposed a way to simplify current approach based on the required number of iterations, memory space, convergence rate and minimum error. In this paper, an updated review on the solution techniques used in load flow studies is presented.

2 CONVENTIONAL METHODS OF POWER STUDY

This involves an iterative method, which require minimal computer storage. In [1], [2] Y-matrix is used for the analysis. A. Garces [1] proposed a linear approximation developed for the load flow of three-phase power distribution systems. The approximation is on complex numbers, unlike other conventional load flow formulations, whose approximation is developed on a real number. Equation (1) shows the first step equation for the approximation. The method is independent of the R/X ratio and it can be employed for both a balanced and unbalanced system. Despite its simplicity, it is very accurate compared to the conventional back-forward sweep algorithm. The percentage error for this approximation is calculated in (2). The error calculated in every point from Fig.1(a) results in the filled area in Fig.2(b). Error for both three-phase and single-phase between the proposed linearization and a conventional one is evaluated using (3), where Vk is the voltage in bus k is calculated using conventional method and Vk(approx) is the voltage from the proposed approach. Fig. 2 shows the result for the three-phase and single-phase systems.

$$f(\Delta V) = 1/(1-\Delta V) \quad (1)$$

$$\Psi(V) = 100.||(1/V-(2-V)|| \quad (2)$$

$$\epsilon_\kappa = ||V_\kappa - V_\kappa(aprox)|| \quad (3)$$

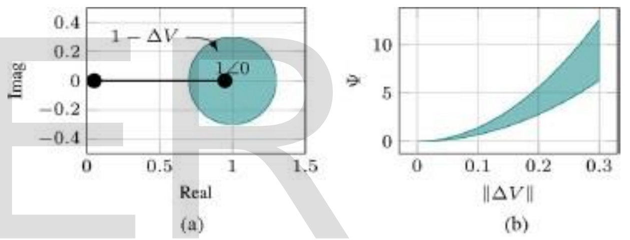

Fig. 1. Schematic representation of the proposed linearization. (a) Values of in the complex plane. (b) Total error in percentage[1]

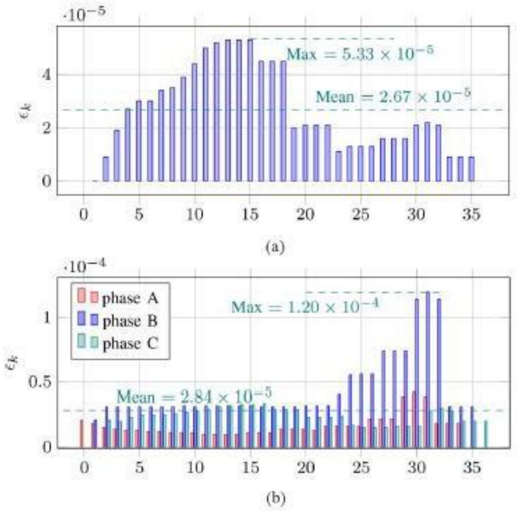

Fig. 2. Error between the back-forward sweep algorithm and the proposed linear power flow. (a) Single phase case. (b) Three-phase unbalanced case. [1]

A modified current injection method for power flow analysis in heavy-meshed DC railway networks With non-reversible substations is proposed in [2]. In addition to simulating the nonlinear and non smooth behavior of the trains, the proposed algorithm can simulate reversible IGBT-based and non reversible diode-based substations present in the. Another key aspect of the proposed method is that it is also valid for heavily meshed networks. The assumptions in this method are that all the DC nodes connected to the AC system are represented by a line connected to a DC slack nodes. Also, the trains are considered as power loads (traction mode) or generators (braking mode). Equation (4) is used for estimating the line impedance (in m) representing the connection between the DC and the AC system when the substation is in conductive mode. Fig 3 shows a detailed case study with

$$R_{sub} = k * \frac{V_{DC}^2 * V_{cc}}{10^2 * P_{sup}} \quad (4)$$

$$i_B = Y_B * (B_N * V_N + B_S * V_S) \quad (5)$$

$$i_U = Y_U * (U_N * V_N + U_S * V_S) \quad (6)$$

$$i_N = (Y_{BS} + Y_{US}) * V_S - C_N^T * i_L \quad (7)$$

three substations (S1, S2 and S3) and two trains (T1 and T2). The network lines or branches are classified into two groups Bidirectional branches Unidirectional branches the current through both of them are given by (5) and (6) respectively, while the total injected current is given by (7). The proposed algorithm shows a better convergences and speed than the previous algorithms.

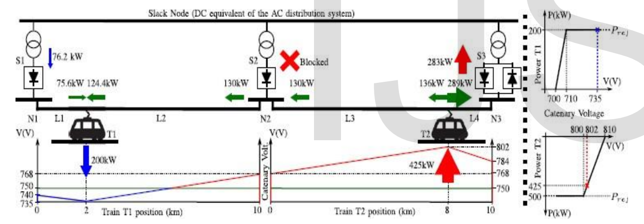

Fig. 3 **Figure 3.** Detailed case of study with three substations (S1, S2 and S3) and two trains (T1 and T2). [2]

Although the performance using Y-matrix is satisfactory on different systems, however, the main drawback is its converging time. To overcome this deficiency, the Z-matrix methods is developed, which converge more reliably. In [3] a harmonic load flow analysis of radial distribution system in the presence of distributed generation is proposed, Fig. 4 shows harmonic voltage on each bus of each order for IEEE-33 bus. Due to increase in the use of non-linear devices, the harmonic distortion is increased in the power system. This paper represents the distribution system load flow and harmonic load flow for IEEE 33-bus radial system. This paper represents the effect of DG on harmonics. The voltage total harmonics is calculated and shown. The %THD obtained at each bus after placement of DG is within standard limits. The results shows that the optimal allocation of DG can reduce the system losses as well as the harmonic distortion. Also the voltage profile is improved. The optimal location of the DG is obtained from various sensitivity indices. The current equivalent injection of bus i at the kth iteration of load flow analysis is calculated using (8)

$$I_i^{(k)} = \frac{S_i^*}{V_i^{(k)*}} * \frac{(P_i + jQ_i)^*}{V_i^{(k)*}} \quad (8)$$

Other conventional methods like Newton-Raphson method and factorization Method has been shown to have powerful convergence properties. These methods are employed by many researchers. In [4], a GPU-based fatch LU-factorization (9) solver for concurrent analysis of massive power flows is proposed, Fig. 5 shows the inter-column parallelism of an eight-order matrix case. By packaging massive LU-factorization tasks in MPFP to formulate a larger-scale problem, the proposed batch solver achieves higher level of parallelism and better memory-access efficiency, Fig. 6 shows Design scheme of proposed batch LU-factorization algorithm. The proposed batch-solving method lays a critical foundation for MPFP and is practically very promising

$$A_i = L_i * U_i \quad (9)$$

In [5], the authors presented a novel algorithm called weather-dependent power flow (WDPF) algorithm that is more superior to the regular power flow (PF). The algorithm assimilated well available weather measurements which have been carefully investigated. To ensure that the proposed algorithm is efficient, IEEE 30-bus network was used to investigate three situations using available real weather data. Compared to the conventional PF, the result indicated the importance of accurate weather effects in order to ensure efficient power system studies. Also, the branch conductor temperatures, resistances and losses can be better estimated by using the

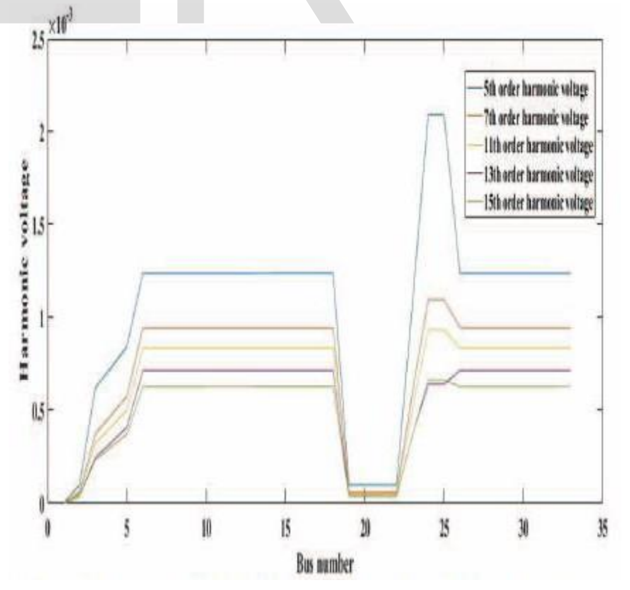

Fig. 4 Harmonic voltage on each bus of each order for IEEE-33 bus. [3]

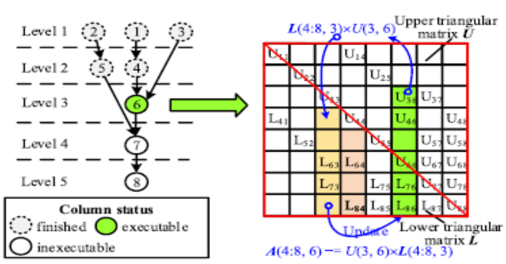

Fig. 5 Inter-column parallelism of an

WDPF algorithm. However, it should be noted that the WDPF algorithm takes a longer time compared to conventional methods.

The authors in [6] reported a power flow correction strategy to avoid inefficient and repeated adjustments in the system. Quasi-steady method was used to obtain the multi machine system sensitivity matrix using the Taylor series expansion of the power flow. After analysis, Fig. 7 indicates that after correction control, the nodal voltages are still within the allowable range while Fig. 8 shows that the power flow more clearly. Also, in [7], the authors used MATLAB to compare the IEEE distribution system analysis and load flow analysis solution using the Newton-Raphson method. Less load flow iteration was discovered when the simulink model was used.

Also, in [8] the authors extended the conventional DC power flow approximation to include lossy networks. Lossy DCPF and Lossy Modified DCPF were introduced to get a rapid convergence of sequence and improvement in the order-of-magnitude. Also, in [9], the Romanian power 110Kv by 20Kv distribution was retrofitted to respond to the ever increasing need for energy. Load flow analysis was also carried out to mitigate power loss and maintenance cost.

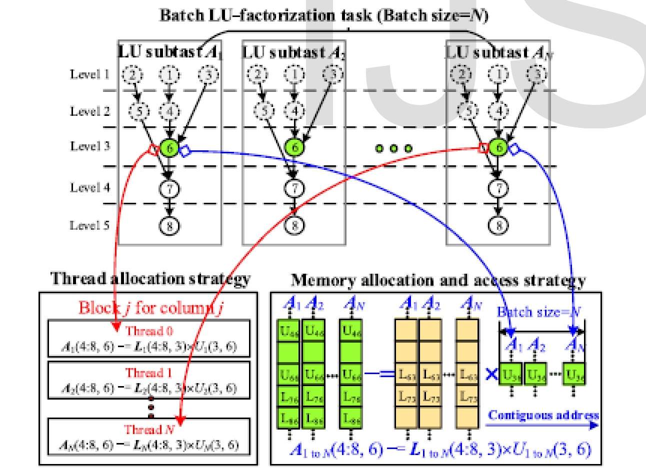

Fig. 6. Design scheme of proposed batch LU-factorization algorithm. [4]

In [10], the power factor and voltage level changes were observed in a load flow analysis using the Newton-Raphson method, in order to observe the effect of increasingly demand for renewable energy sources. The different levels of distributed generation was observed to not have much effect on the level of voltages of the buses, thereby, providing energy balance. In [11], a new type of FACTS controller, known as Static Var Compensator (SVC), consisting of filter elements, Thyristor Controlled Reactor (TCR), Thyristor Switched Capacitor (TCR) and some filter elements was used for minimizing losses as well as stabilising voltage in a power system from bus 1-9 using load flow analysis. In [12], the authors discussed a retrofitted Romanian substation by replacing the old circuit breakers with new gas insulated SF6 switch gear in order to account for the increasing demand for energy and to reduce coast as well as increase energy supply.

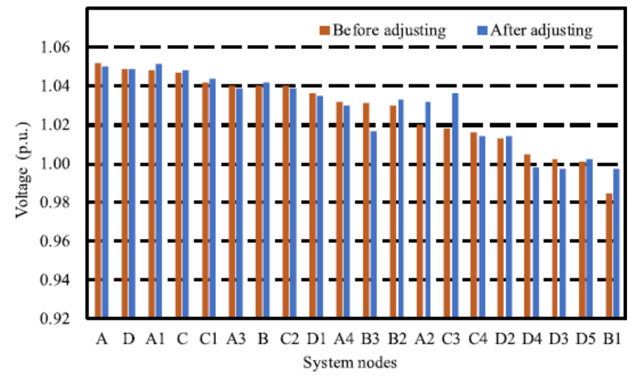

Fig. 7. Nodal voltages before and after power flow correction control. [6]

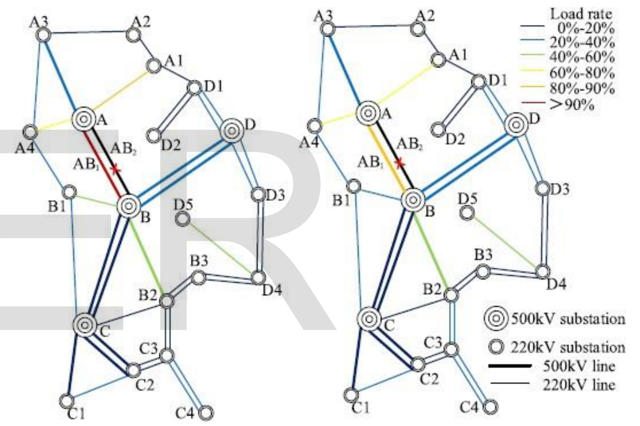

Fig. 8.Line load rates before and after power flow correction control. [6]

In [13], a proposed HPFC model using Newton Raphson power flow analysis was discussed. The model was subjected to varying load in order to determine the selected line outages ranking as well as buses. Less severe contingency and critical line system was achieved. Also, in [14],the authors used DLF matrix to formulate the load flow model. The different loading condition for load model was carried out for IEEE 69-bus and 12-bus system. The results show that the DG improved the convergence, with better efficiency, for the different loading conditions.

3 NON CONVENTIONAL METHODS OF POWER FLOW STUDY

Due to the high demand to meet the requirement of power flow, non-conventional methods are proposed In [15] - [29] In [15], the authors presented a novel algorithm for analysing load flow. Non-synchronised measurements at the microgrids and DGS, as well as the main substation was employed. The results obtained showed that this new method is cost-effective, does not require prior information about the microgrids and DGs that are connected to the grid. This novel method can also be effective to the operators in the distribution system.

In [16], a load model that involves the bottom-up time variant approach was investigated to account for the changing voltage dependencies of the load. This approach is used to model the electrical demand of an household in order to explain the the three phase probabilistic power loss factor (PLF) of a three-phase residential distribution network. This method reduced the probability of volatage violations cause by Electric Vehicle (EV). Also, in [17], the authors explained the solutions to various load flow problems in distributed generation system using probabilistic load flow analysis. This analysis is used to ensure that the distribution system is compatible with the varying generation capacity. This method is used to test the accuracy and efficiency of a radial 30 bus distribution network. More efficient handling of the voltage abnormality was observed.

In [18], the authors introduced a probabilistic load flow (PLF) study using the hybrid method to account for the uncertainty in the photo voltaic generation. It also presented a temperature-augmented PLF sensitive matrix model. Also, in [19],the authors introduced global sensitivity analysis (GSA) to evaluate the effect of uncertainties in the power flow of islanded micro grids (IMGs) by first using a probabilistic power flow. The GSA helps to identify the factors that may affect IMG power flow. The model was tested using 69-bus and 33-bus systems. Compared with other methods, the IMG system is more powerful.

In [21], a system model level for Wireless Power Transfer (WPT) that includes all the important blocks is proposed. For all the blocks, the power loss and efficiency can be determined with more precision using this improved model. The proposed model is validated with experimental results. Fig. 9 shows the WPT system that includes the rectifier, power amplifier, matching networks, etc. In [23], the authors introduced the artificial bee colony algorithm as one of the herd based algorithms used to mitigate the fuel cost in smart grid load flow analysis. This algorithm saves time and also more flexible compared to other algorithms.This makes the algorithm useful in powerful systems that require faster results. Due to the ineffectiveness of the Newton-Raphson algorithm (NRLF) over large power systems, the authors in [28] proposed an artificial neural networks (ANN) model to accurately analyse power systems. This ANN is tested on a 380KV power line in Saudi Arabia. The results revealed that the ANN can solve load flow faster that the conventional Newton-Raphson method. In [23] optimum fuel cost in load flow analysis of smart grid by using artificial bee colony algorithm is proposed. The process of the artificial bee colony algorithm requires a four-stage cycle: the initial stage, the worker-bee stage, the onlooker-bee stage, and the scout-bee stage. The artificial bee colony used in the calculation of optimum fuel cost in smart flow grid analysis can give faster results than other algorithms and it is easier to program especially because of the small number of parameters.

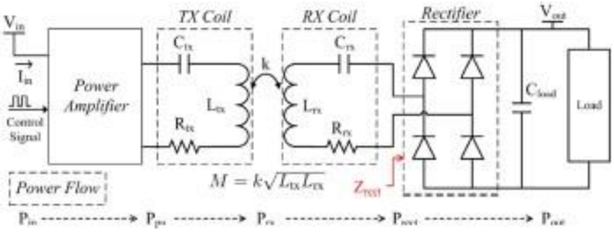

Fig. 9. Typical WPT system with the SS topology. [21]

I. CONCLUSION

This paper presented the conventional and non-conventional methods for load flow analysis currently available in literature. This analysis give an insight into the current methods, analysis, and results of the present state-of-the-art. This can give researchers information into the available methods, as well as make comparison and possible improvement.

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