

Optimal Radial Distribution Network Reconfiguration Scheme Considering Type Two Distributed Generation Placement to Mitigate Power Losses and Voltage Profile Improvement

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ABSTRACT

This research aimed to develop an optimal radial distribution network reconfiguration scheme considering type two distributed generation placement to mitigate power losses and improve voltage profile. The backward/Forward Sweep power flow method will be used to evaluate the steady state condition of the system. A meta-heuristic Spring Search Optimization algorithm technique inspired by three distinctive modes: the shuffling mode, sprawling mode, and random behavior will use for optimal network reconfiguration and DG placement and sizing on a standard IEEE radial distribution network. This research work will implement using MATLAB 2019a. The effectiveness of this technique was tested on standard IEEE 16-bus, 33-bus, and 69-bus radial distribution networks. Four scenarios will be analyzed, the total base case power losses and minimum voltage of IEEE 16, 33, and 69-bus network prior to and after network reconfiguration and distributed generation placement on each scenario. The result will be validated via comparison with the work of using active and reactive power loss and voltage profiles as performance metrics.

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INTRODUCTION

The distribution network represents the last connection between the customers and the bulk power system where electricity is carried from the transmission network to the consumer's (loads) ends. High network losses and poor voltage profiles are usually characterized by distribution networks. This is because of the low voltage level and high current in the distribution network. For effective coordination and protection, distribution networks are usually configured radially [27]. Distribution networks use normally closed switches (sectionalizing-switch), and normally opened switches (tie-switch) [12]. The rapid expansion of distribution networks has been recorded as a major cause of excessive power loss; hence the voltage stability and excessive power losses of the distribution systems have become an important issue [35]. Much research has been conducted for loss reduction and voltage

stability improvement in distribution networks such as capacitor placement, placement of DG, reconfiguration, and load management [25], [36].

Distribution Network Reconfiguration (DNR) is a technique that changes the topology of the distribution network by changing the close/open status of the sectionalizing/tie switches while respecting system constraints and satisfying the operator's objectives [34]. Reconfiguration is used for service under faulty conditions, network overload relief and voltage profile improvement through load balancing, outages, and maintenance planning for power loss minimization are the by-products of reconfiguration [25]. Classical techniques to solve the reconfiguration problem are ineffective due to their radial constraints and the discrete structure of their switches, hence the necessity for computer-based techniques was born. Some of the algorithms in

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the literature are based on heuristic search techniques [21]. Heuristics techniques are bedevilled with iterative time hence, difficulty in obtaining optimal configuration, hence, a new meta-heuristic technique is being proposed for optimal solutions [36]. Therefore, for the purpose of optimality, fast convergence, and accuracy, this research used search space algorithms. Distributed Generation (DG) is a collective term that covers generation of micro-level energy levels using renewable and non-renewable sources such as solar, wind, geothermal, and diesel generators of micro-level energy, cited near the end user location [21]. Renewable energy sources contribute to meeting the energy demand because of the following obvious reasons; increase in cost, resultant pollution, and probable depletion of fossil fuel [39]. The distribution power losses can be divided into real and reactive power losses. Compared to the effect of reactive power loss in the system, the real power loss (I^2R) affects the efficiency of the power transfer and leads to a poor voltage profile [19]. To mitigate the effects of losses and voltage profiles on the distribution

network, researchers have proposed different methods of loss reduction techniques such as feeder reconfiguration, capacitor placement, conductor grading, and DG installation [38]. All these methods are involved with passive elements except DG unit placement. Power flow analysis is the determination of a true state of a power network for a set of specific load demands and power generation. This involves the solution of a set of non-linear iterative power flow equations [12]. The size and complexity of the present-day distribution networks have increased exponentially due to the large number of interconnections and continuously increasing energy demand, [32]. The distribution network radial topology constraint, high ratio of line resistance to reactance ratio (R/X), [27]. Due to the peculiar characteristic of radial distribution network therefore this research considered a load flow algorithm that could handle large distribution network and converges very fast, to this end backward/forward sweep technique is used.

METHODOLOGY

- 1.1 Determination of base case network parameters using Backward/Forward Sweep Algorithm. The following steps were followed. Construction of network's line data matrix, bus data matrix and define the source voltage. Execution of backward sweep, by logically going from each node back to the source while the power flowing on the network branches and respective branch power losses were computed. Execution of forward sweep, by logically going from the source to every other node while the voltage drops along the branches and then the voltages of the network buses are being computed based on results obtain in above statement. Updating the voltages at the using the results obtain before this statement.
- 1.2 SSO implementation for Network Reconfiguration and DG Installation Initialization of SSO and network parameters. Formulation of the objective function. Assignment of weight for the fitness functions

- (power loss and voltage deviation), evaluate the fitness functions and check constraints for each particle in each of the iteration. Update the best particle. Run SSO to obtain the optimal Reconfiguration, DG Installation, location. and sizing. Network performance analysis prior and after network reconfiguration considering DG placement. Use backward/forward sweep to run the power flow. Compute the bus voltage and change in active and power. Update the network with the best solution.
- 1.3 Network performance analysis prior and after network reconfiguration considering DG placement. Use backward/forward sweep to run the power flow. Compute the bus voltage and change in active and power. Update the network with the best solution.
- 1.4 Implementation of the proposed technique in terms power loss and voltage profile on standard IEEE 16-bus, 33-bus and 69-bus radial distribution networks and Validation using the work of [36]. Loading of line and bus data of IEEE 16-bus, 33-bus and 69-bus.

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Analysis of base power flow. Initialization the SSO parameters Application of SSO with the formulated objective functions and constrains. Analysis of final power flow for reconfiguration and DGs placed optimally. Validation of the proposed technique using the work (35).

RESULTS AND ANALYSIS

For Network Reconfiguration for IEEE 16-bus Network and Base case, power flow analysis was carried out on IEEE 16-bus network using backward/forward sweep to determine the true state of the network; total base case power loss of 62.44kW was obtained. Figures

4.1 and 4.2 show the power flow and voltage profile results during reconfiguration only, a total power loss of 17.23kW is obtained. After the network reconfiguration using SSA, the power loss reduced from 62.44 to 17.23kW representing 12.12% power loss reduction. This is shows in Figure 4.2 that the minimum base case voltage of 0.9403p.u occurred at bus-12 and after reconfiguration the voltage magnitudes improved from 0.9403p.u to 0.9802p.u. It can be seen that the developed technique recorded a percentage power loss reduction of 12.12% with a switching configuration of 9, 10 and 11 as against the initial configuration of 5, 6 and 4 recorded in the base ca

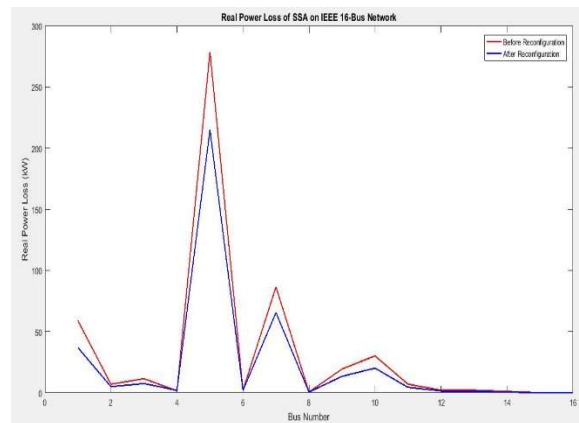


Figure 1: Power Loss Profile before and after reconfiguration for IEEE 16-Bus Network.

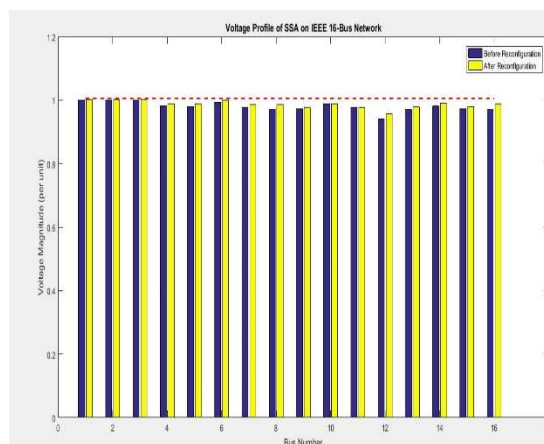


Figure 2: Voltage Profiles before and after reconfigurations for IEEE 16-Bus Network.

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Scenario II: With Network Reconfiguration for IEEE 33-bus Network.

Power flow analysis was carried out on IEEE 33-bus network using backward/forward sweep to determine the initial state of the system, a total base case power loss of 96.3407kW was obtained. Figures 3 and 4 show the power flow and voltage profile results during network reconfigurations. It is noticed from voltage profile results in Figure 4.4 that the minimum voltage of 0.9130p.u occurred at

bus-19. After the network reconfiguration using SSA, the power loss reduced from 96.3407kW to 46.2393kW representing 33.35% power loss reduction and the voltage magnitude improved from 0.9130p.u to 0.9810p.u. It can be deduced that the proposed technique recorded a percentage power loss reduction of 7.44% with a switching configuration of 9, 37, 7, 32, 14 as against the initial configuration of 7, 9, 14, 32, and 37.

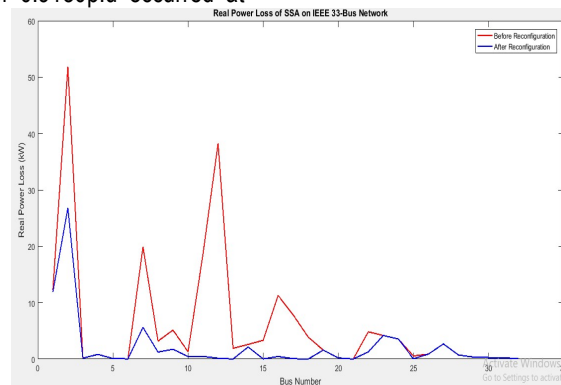


Figure 4.3: Power Flow Profiles before and after Reconfiguration for IEEE 33-bus Network.

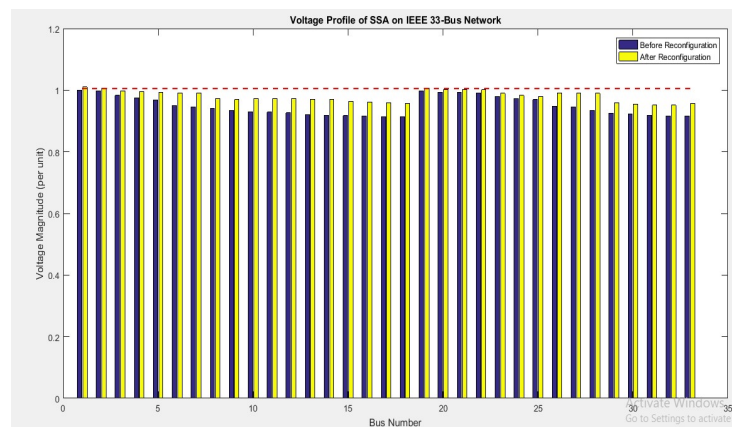


Figure 4.4: Voltage Profiles before and after Reconfigurations for IEEE 33-Bus Network.

Case 2: With Network Reconfiguration for IEEE 69-bus Network.

Figures 5 and 6 shows the power flow and voltage profiles results during network reconfiguration only for IEEE 69-Bus network. The total base case power loss of 223.1394 was obtained. After the network reconfiguration

using SSOA, the power loss reduced from a base case power loss of 223.1394kW to 107.1246kW representing 51.99% power loss reduction. It is also observed from voltage profile result in Figure 4.6 that the minimum voltage of 0.9495. p.u occurred at bus-63 the voltage magnitude improved from 0.9094p.u to

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0.9910p.u. It can be deduced that the proposed technique recorded a percentage power loss reduction of 8.23% with a switching

configuration of 7, 19, 9, 20 and 28 as against the initial configuration of 69, 70, 71, 72, and 73.

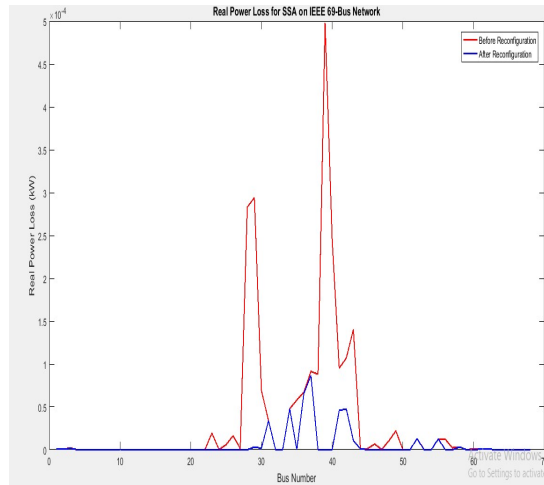


Figure 4.5: Power flow Profiles before and after Reconfigurations for IEEE 69-Bus System

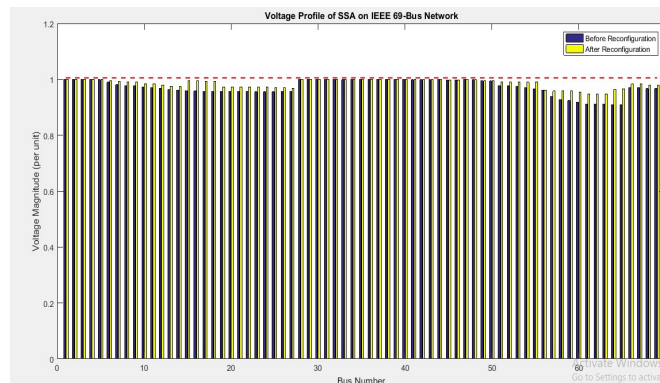


Figure 6: Voltage Profiles before and after reconfigurations for IEEE 69-Bus System

During network reconfiguration, DG installation, location and sizing, the power loss reduces from 224.39kW to 156.09kW representing 69.56% also with voltage improvement from the initial 0.9094p.u to 0.9876p.u

CONCLUSION

Spring Search Optimization Algorithm techniques for the optimal network reconfiguration and sizing of DG on IEEE 16-bus, IEEE 33-bus and IEEE 69-bus has been developed in order to

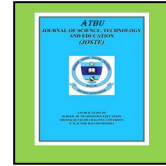
reduce the network power losses and improve voltage profiles. Backward/forward Sweep of power-flow analysis was used to analyse the networks so as to examine the true state of the network. Active power losses minimization and voltage profiles improvement were formulated into a multi-objective functions which satisfied all system inequality constrains. The total base case power losses of IEEE 16-bus network prior network reconfiguration and DG placement is 422.44kW with minimum voltage of 0.9434p.u, but after reconfigurations, the power

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losses reduced to 371.23kW representing 12.12% power losses reduction and the voltages improved to 0.9823p.u. after optimal installation of three DGs on the network, the network power losses further reduced to 308.26kW representing 27.03% power losses reduction with improvement on the voltage magnitudes to 0.9801p.u from 0.9434p.u. During network reconfiguration, DG installation, location and sizing, the power loss reduces from 422.44kW to 371.23kW representing 27.03% also with voltage improvement from the initial 0.9434p.u to 0.9958p.u. The total base case power losses of IEEE 33-bus network without network reconfiguration and DG placement is 317.46kW with minimum voltage of 0.9115p.u, but after reconfiguration, the power losses reduces to 218.26kW representing 31.25% power losses reduction and the voltage improved to 0.9510p.u. After only optimal installation of three DGs on the network, the network power losses further reduces to 59.78kW representing 31.21% power loss reduction with improvement on the voltage magnitudes to 0.9810p.u from 0.9115p.u. During network reconfiguration, DG placement, location and sizing, the power loss reduces from 295.46kW to 149.78kW representing 49.31% also with voltage improvement from the initial 0.9115 to 0.9810p.u. The total base case power losses of IEEE 69-bus network without network reconfigurations and DG placement is 224.39kW with minimum voltage of 0.9194p.u, but after reconfiguration, the power losses reduced to 90.45kW representing 59.47% power losses reduction and the voltage improved to 0.9998p.u. After only optimal installation of three DGs on the network, the network power loss further reduces to 68.30kW representing 69.56% power loss reduction with improvement on the voltage magnitudes of 0.9898p.u from 0.9094p.u.

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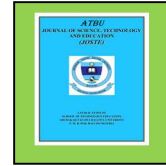
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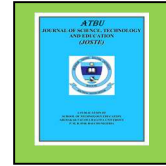
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