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Orginal Article

Loss Reduction and Improvement of Voltage Profile in Distribution System with Unbalanced Loading Conditions Using Chaotic Stochastic Fractal Search Algorithm

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Abstract - *This paper emphasizes the power network reconstructions that restore resources in unbalanced systems. The main objective is to improve the voltage profile and to reduce the power losses at each bus. With two processes of diffuse and update, the developed method is a meta-heuristic to get better results. A description of the solution to the service restoration is also achieved with case studies to show its effectiveness. The solution process established by the Chaotic Stochastic Fractal Search Algorithm (CSFSA) is used to search for switching conditions under unbalanced load conditions for IEEE 33-bus system. Research shows that the right pattern to change whether the opening or closing of switches may appear to give less power loss while satisfying all the constraints. It also highlights service delivery strategies in distribution systems under different considerations.*

Keywords - *Radial distribution system, Feeder reconfiguration, Loss minimization, Bus voltage improvement, Unbalanced system.*

1. Introduction

Various methods have been developed to reduce the power loss of electrical distribution systems while addressing the inevitable inefficiency of system components. Weather conditions, and overloading conditions, among others, begin to malfunction partially. Inefficiencies and failures cause losses and loss of energy. In such cases, system operators initiate methods of retrieving loads independently. Effective methods such as feeder adjustments are considered. The feeder reset involves switching the network topology to the power distribution system by turning on and off the switches that change the power flow from the power station to the consumer. Feeder adjustments help reduce power loss, balance system load, improve voltage profile and increase system reliability and efficiency. Circuit breakers, sectionalizes, and open tie-switches contain key elements for remodeling [1,2].

Distribution network restructuring is usually done to avoid overloading the network branches and minimize system losses. Restructuring is possible for a variety of reasons. Load balancing includes Restructuring according to loading conditions to eliminate overloading on system objects such as converters or queues. With various loading conditions in the system, it may be advisable to reset to minimize real power loss on the network [3]. Rehabilitation is possible in the event of emergencies following the error of separating a line or an error location from active sinners and restoring areas outside the error area. System restructuring can also be done on a healthy network. The redesign is easier in such a healthy network than in faulty networks due to the availability of electrical power and many means of communication.

System imbalance exacerbates the problem of Restructuring due to the number of categories. The three phases in power distribution systems need to be considered simultaneously instead of the equivalent presentation of one phase. Efforts have been made to restructure distribution systems to achieve a reduction in losses and, thus, cost-effective ways. Techniques such as genetic algorithms, imitation, and heuristic reduction have been used to reduce losses [4,5,6].

This paper contributes to understanding the premium solution for restructuring unequal distribution systems to reduce power loss and improve voltage profile. The notable limitations of the system include the format of radial configuration, feeder limitations, load point limits and zero load point distortions. The solution is a three-phase electrical flow algorithm. A three-phase algorithm is used to solve network power losses and bus voltages, according to the CSFS Algorithm. This paper also includes plans to restore service in distribution systems where remodeling is the solution. With the use of smart grid concepts that have emerged with the installation of an automated system and advanced meter infrastructure, the problem of replacement has changed. The rest of the paper is set out as follows: Segment II gives the analysis of Three Phase Power Flow. Segment III includes a problem formulation. Segment IV describes the overview of the Chaotic Stochastic Fractal Search Algorithm. Segment V exhibits simulation results, and segment VI gives conclusions.

2. Analysis of Three Phase (3-∅) Power Flow

Power flow is a key component of power system network analysis. Because of the inevitable inequalities in energy structures caused by uninterrupted transmission lines and inequalities in loading, power drift analysis regarding the suspension of three phases(3-∅) of the electricity gadget is needed for correct planning[19]. The main objective of this section is to find out the active and reactive (VAr) powers flow in each feeder [29].

Usually, three-dimensional measurements and loading using switching transmission traces are used to apply energy structures to static nation evaluation. However, this isn't continually the case, especially in radial distribution systems. As a result, methods based on single-phase evaluation are no longer healthy, and the profile represents the three unequal segment networks. The approach used as a prime tool to resolve the hassle of energy imbalance is primarily based on the quantity of the real segment and all the best equipment accompanied within the section links. Therefore, the answer for the go-with-the-flow of power is likewise an unequal case, and therefore special remedy is needed to remedy such networks [8, 9]; the conductors of each line phase in the network can be represented by means of the corresponding le version. The impedance of the series capacitance and the shunt capacitances of the 3-∅ line of complex matrixes of 3 × 3.

The admittance matrix of buses i and j is a 6×6 matrix in (1) in which Z is the series impedance and $Y$is the shunt admittance

$$Y_{ij} = \begin{bmatrix} Z^{-1} + \frac{1}{2}Y & -Z^{-1} \\ -Z^{-1} & Z^{-1} + \frac{1}{2}Y \end{bmatrix} \qquad (1)$$

Voltages and currents of 3x1 vectorsV_i,V_j,I_i andI_j in fig.1. Above are associated with

$$\begin{bmatrix} I_i \\ I_j \end{bmatrix} = Y_{ij} \begin{bmatrix} \mathrm{V_i} \\ \mathrm{V_j} \end{bmatrix} \qquad (2)$$

For a system has n buses, the bus voltage vector (V_{bus}) and bus current vector (I_{bus}), they are described as

$$V_{bus} = [V_1^a, V_1^b, V_1^c, V_2^a, V_2^b, V_2^c, \ldots., V_n^a, V_n^b, V_n^c]^T \qquad (3)$$

$$I_{bus} = [I_1^a, I_1^b, I_1^c, I_2^a, I_2^b, I_2^c, \ldots., I_n^a, I_n^b, I_n^c]^T \qquad (4)$$

Where V_i^p is complex voltage and I_i^p is current of phase p in bus i (injected current).

$$\mathrm{I}_{bus} = Y_{bus} V_{bus} \qquad (5)$$

Where $Y_{bus} = [Y_{ij}^{pm}]$a complex 3n x 3n matrix, its function links voltage V_j^m to the current I_i^p.
Rewriting equation (5) will become (6).

$$I_i^p = \sum_{j=1}^n \sum_{m=a}^c Y_{ij}^{pm} V_j^m \qquad (6)$$

The active (real)and reactive powers [31] are in equations (8) and (9).

$$S_i^p = P_i^p + Q_i^p \qquad (7)$$

$$P_i^p = |V_i^p| \sum_{j=1}^n \sum_{m=a}^c |V_j^m| [G_{ij}^{pm} cos\theta_{ij}^{pm} + B_{ij}^{pm} sin\theta_{ij}^{pm}] \qquad (8)$$

$$Q_i^p = |V_i^p| \sum_{j=1}^n \sum_{m=a}^c |V_j^m| [G_{ij}^{pm} sin\theta_{ij}^{pm} - B_{ij}^{pm} cos\theta_{ij}^{pm}] \qquad (9)$$

Where p= phases a, b and c

P_i^p,= Active power for phase p at bus i=1,2,3….,n
Q_i^p = Reactive power for phase$p$.
$Y_{ij}^{pm} = G_{ij}^{pm} + jB_{ij}^{pm}$
V_i^p = voltage for phase p of bus i
$\theta_{ij}^{pm} = \theta_i^p - \theta_j^m$

3. Problem Formulation

The objective function is defined in 3-∅ distribution system as follows:

$$\mathrm{Min}T = \sum_{k=1}^{Nl} P_k \qquad (10)$$

Where $T = Total\ loss\ of\ power\ in\ 3 -$
$\phi\ distribution\ system\ \ Nl =$
$Number\ of\ branches\ in\ the\ \ 3 - \phi\ distribution\ system$
$P_k = Loss\ of\ power\ in\ branch\ k$

The loss of power in branch k is obtained.$P_k$in equation(10) can be written as[30]

$$P_k = [I_k]^T [R_k] [I_k] \qquad (11)$$

Where

$[I_k]$ =3-$\emptyset$Current matrix and
$[R_k]$ =3-$\emptyset$Resistance matrix of branch k
$[I_k]$,$[R_k]$ are represented as:

$$[I_k] = \begin{bmatrix} I_k^a \\ I_k^b \\ I_k^c \end{bmatrix} \tag{12}$$

$$[R_k] = \begin{bmatrix} r_k^{aa} & r_k^{ab} & r_k^{ac} \\ r_k^{ba} & r_k^{bb} & r_k^{bc} \\ r_k^{ca} & r_k^{cb} & r_k^{cc} \end{bmatrix} \tag{13}$$

Where $[I_k^p]$ = Current flow in phase p of branch k
$r_k^{aa}, r_k^{bb}, r_k^{cc}$ =Self-resistance of phase conductors in a, b and c of branch k

$r_k^{ab}, r_k^{ac}, r_k^{ba}, r_k^{bc}, r_k^{ca}, r_k^{cb}$ =Mutual resistance between phase conductors of branch k

The constraints for the objective function in (10) are as follows.

1) $3 - \emptyset\ power\ flow\ equations\ in (8) and (9)$
2) $The\ limits\ of\ Bus\ voltage$:

$$V^{p,min} \le V_i^p \le V^{p,max} \tag{14}$$

3) $Feeder\ capability\ limits$

$$\left| I_k^p \le I_k^{p,max} \right| k \in \{1,2.3 \dots l\} \tag{15}$$

4) $Radial\ configuration\ format$
5) $No - load\ point\ interruption$
$Where \quad NI = number\ of\ feeders$
$V^{p,max}, V^{p,min},\ I_k^{p.max} = Maximum\ and\ Minimum\ voltage\ and\ Maximum\ current\ for\ phases\ a, b\ and\ c$[18].

4. Overview of Chaotic stochastic Fractal Search Algorithm

In this paper, a CSFS Algorithm is used [13,14] to determine the reconfiguration problem in unbalanced distribution systems with different load conditions. During this analysis, to enhance the performance, a chaotic map is integrated with the traditional SFSA [15,16]. The steps involved in the CSFSA algorithm to solve the unbalanced radial distribution network are given below[31].

- Radial Constraints Checking.
- Development of CSFS algorithm.
- Diffusion and updating Process
- Chaotic Map Integrated in SFSA [32]

5. Results and Discussion

A 33-bus radial distribution system with 37 branches illustrates the proposed technique. The tie line switches in the network's loops L1 to L5 are 33, 34, 35, 36, and 37, as shown in Fig.1. The system's operating voltage is 12.66 kV [11] [12]. Before reconfiguration, the power loss of this system was 202.771 kW for opened switches 33 and 34,35,36,37. The developed methodology is implemented using MATLAB software with Intel(R) Core i5 @2.20GHz 8.00GB RAM[22].

The following are the investigations into the development of feeder reconfiguration under unbalanced loading conditions.

Test Case 1: involves the system being in a balanced condition.
Test Case 2: involves 5% unbalanced loading conditions
Test Case 3: involves 30% unbalanced loading conditions
Test Case 4: involves 50% unbalanced loading conditions

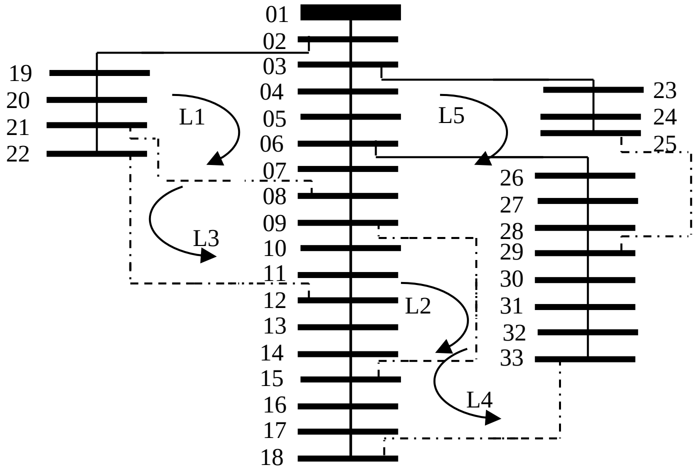

Fig. 1 Radial Distribution system for 33-bus

Table 1. Test results of case study

Test case no	Opened switches	Power loss Before Reconfig-uration	Min Voltage	Power loss After Reconfig-uration	Min Volt
1	7,9,14,37,32	202.77	0.9122	131.86	0.9413
2	7,9,14,25,16	184.67	0.9011	140.26	0.9408
3	20,9,14,25,36	298.21	0.7533	165.03	0.9411
4	20,9,14,25,16	388.24	0.7827	170.57	0.9333

Table 1 shows the experimental results of the proposed system under different loading conditions, as mentioned above

The opened switches for optimal feeder reconfiguration obtained in case.1 have a power loss of 131.86 kW. After reconfiguration, the amount of reduction of power loss is 65.02%. From simulation results, it is observed that the node voltage has improved from 0.9122 per unit to 0.9413 per unit.

For test case 1, the simulated results of the voltage profile and power loss convergence after reconfiguration has shown in Fig.2 and Fig.3, respectively.

In test case 2, the opened switches for optimal feeder reconfiguration have a real power loss of 140.26 kW. The reduction in power loss after reconfiguration is 31.66%. From experimental results, the node voltage has improved from 0.9011 per unit to 0.9408 per unit.

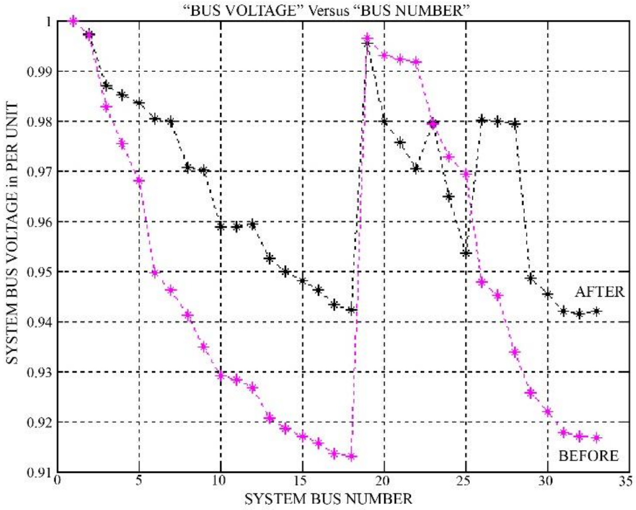

Fig. 2 Voltage Profile (Test case –I)

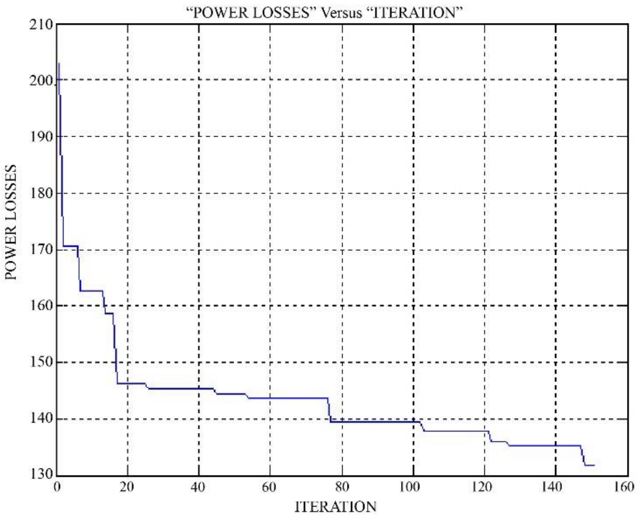

Fig. 3 Power loss Convergence Characteristics (Test case –I)

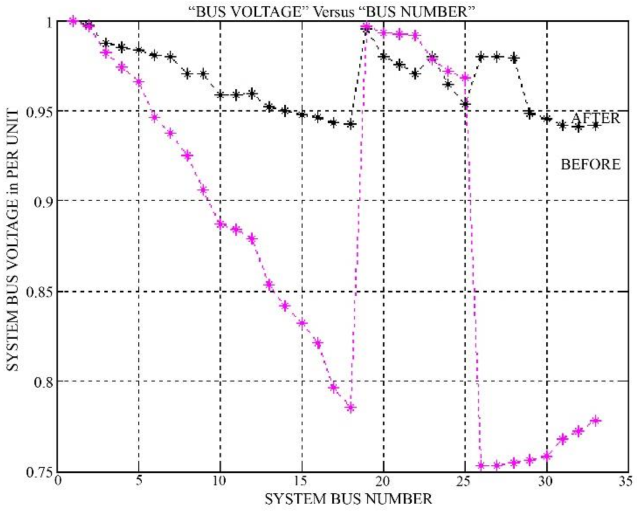

Fig. 4 Voltage Profile (Test case –II)

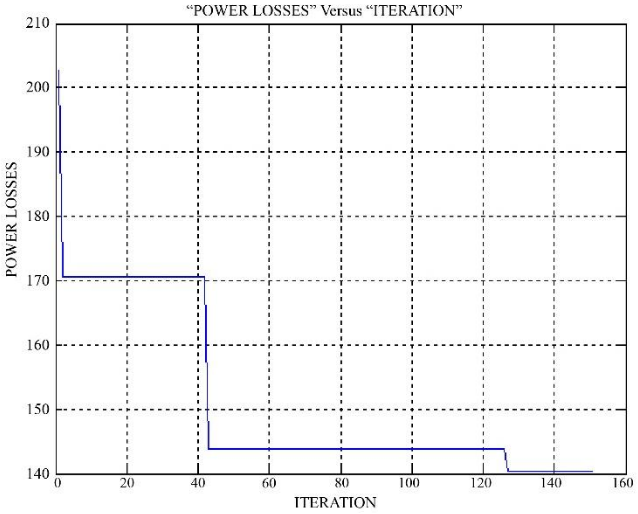

Fig. 5 Power loss Convergence Characteristics(Test case –II)

For test case 2, the simulated results of the voltage profile and power loss convergence after reconfiguration has shown in Fig.4 and Fig.5, respectively.

In test case 3, the opened switches for optimal feeder reconfiguration obtained are 20, 9, and 14,25,36, which have a power loss of 165.03 kW. The reduction in power loss after reconfiguration is 33.43%. From experimental results, the node voltage has improved from 0.7533 per unit to 0.9411 per unit.

For test case 3, the simulated results of the voltage profile and power loss convergence after reconfiguration has shown in Fig.6 and Fig.7, respectively.

In test case 4, the opened switches for optimal feeder reconfiguration have a power loss of 170.57 kW. The amount of power loss decrease after reconfiguration is 38.71%. From experimental results, it is observed that the node voltage has improved from 0.7827 per unit to 0.9333 per unit.

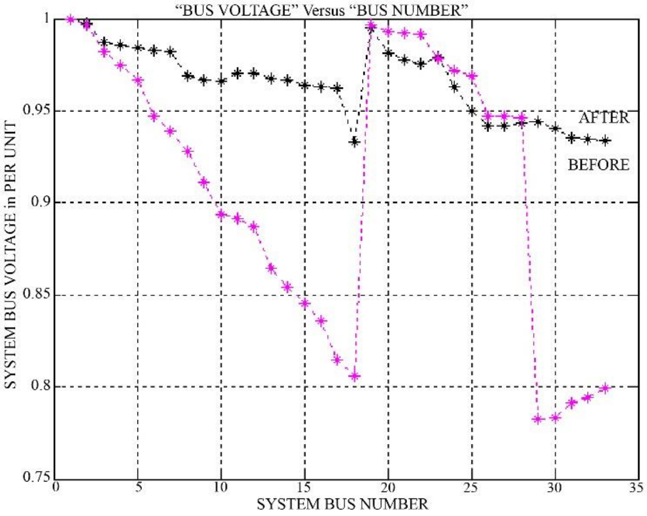

Fig. 6 Voltage Profile (Test case –III)

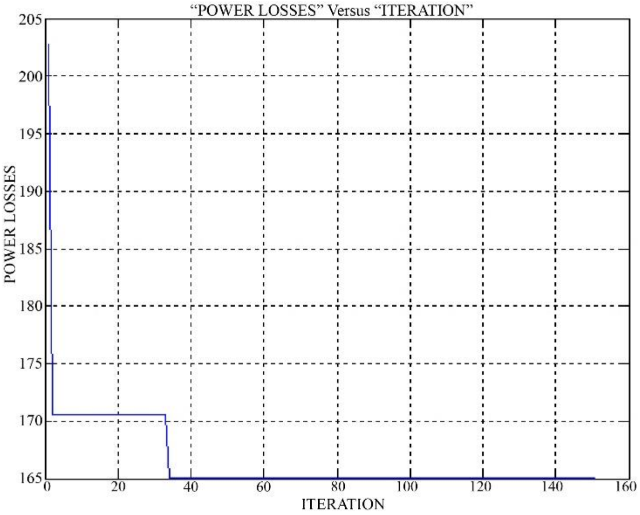

Fig. 7 Power loss Convergence Characteristics (Test case –III)

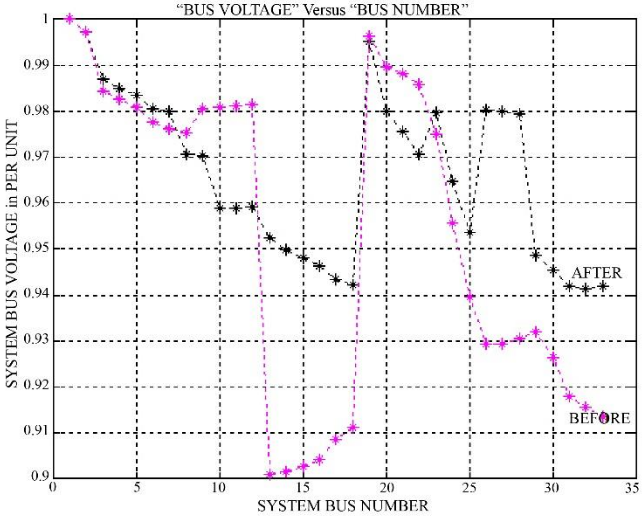

Fig. 8 Voltage Profile (Test case –IV)

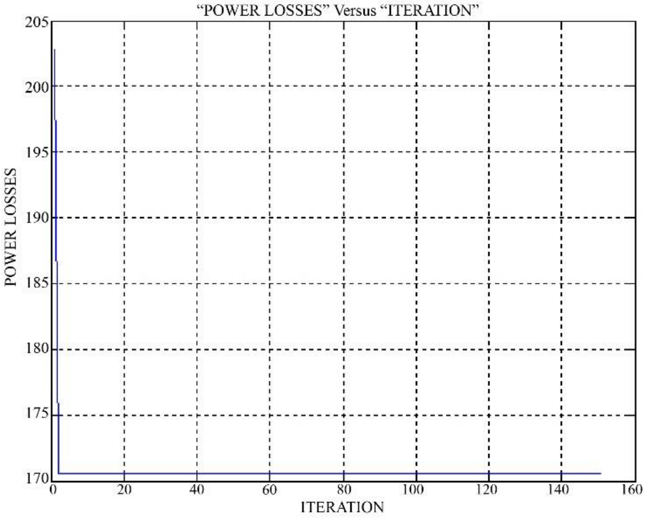

Fig. 9 Power loss Convergence Characteristics (Test case –IV)

For test case 4, the simulated results of the voltage profile and power loss convergence after reconfiguration has shown in Fig.8 and Fig.9, respectively.

5. Conclusion

The method of CSFS Algorithm based optimization has been illustrated in this paper to find the maximum appropriate neighborhood foundation for a distribution system below unbalanced loading conditions. The major function offers 3-phase power flow, bus electricity limits, cutting-edge distribution of feeders, radial configuration format, and no load factor distortion. The feasibility of the suggested approach is illustrated using a 33-bus radial distribution system. Research consequences with diffusion of unbalanced loading situations suggest that the phase partitions and tie replacement can be visible to generate much less power loss, supplying sizeable savings in annual costs. Superior methods provide a quick answer; however, the degree of accuracy is at the bottom. Studies remain being carried out.

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