Analysis on Improved Branch Exchange Method for Enhanced Distribution System Reconfiguration

[1] Nwe Nwe Yin, [2] Myint Thuzar, [3] Zin Mar, [4] Ei Phyo Thwe
[1] Ph.D. Candidate, [2] Professor, [3] Ph.D. Candidate, [4] Assistant Lecturer
Department of Electrical Power Engineering, Mandalay Technological University
Mandalay, Myanmar
[1]rabbitnny85@gmail.com, [2]mthuzar.3@gmail.com, [3]zinmarhlaing2@gmail.com, [4]eiphyo2012@gmail.com

Abstract: *In Myanmar, a lot of power is remarkably dissipated in distribution system. Accurate loss reduction and voltage profile improvement are the critical components for efficient electrical distribution system. There are several ways for line loss reduction and voltage profile improvement. Specifically, network reconfiguration methods are employed for the improvement of the system. Network reconfiguration in distribution systems is performed by opening sectionalizing (normally closed) and closing tie (normally open) switches of the network. In this paper, the improved branch exchange method is presented in comparison with existing branch exchange method. For the performance analysis, an iterative algorithm is employed by using ETAP 12.6 software, which follows an AC optimal power flow problem. The most important benefit of the proposed system is loss reduction, voltage profile improvement and freeing up the power system capacity. The proposed method is tested on 106 buses radial distribution system of Naypyitaw City, Pyinmana Township, where long-length, overloaded lines and high level of power dissipation is occurred in this system.*

Keywords: *Radial Distribution System, Network Reconfiguration, Loss reduction, Voltage regulation, Improved branch exchange method*

1. INTRODUCTION:

The distribution systems deliver power to the customers from a set of distribution substations and these are normally configured radial for effective co-ordination of their protective systems.

There are two types of switches used in primary distribution systems; sectionalizing switches (normally closed) and tie switches (normally open). They are designed for both protection and configuration management in the system. Under normal operating conditions, feeders are frequently reconfigured by changing the open/closed state of each switch in order to reduce line losses or to avoid the overloading network branches. Since there are many candidate-switching combinations possible in a distribution system, finding the operating network reconfiguration becomes a complicated combinatorial, non-differentiable constrained optimization problem.

The radial constraint and discrete nature of the switches prevent the use of classical techniques to solve the reconfiguration problem. Most of the algorithms in the literature are based on heuristic search techniques.

Distribution system reconfiguration for loss reduction was first proposed by Merlin and Back [1]. They employed a blend of optimization and heuristics to determine the minimal-loss operating configuration for the distribution system represented by a spanning tree structure at a specific load condition. Since then, many techniques have been proposed. A branch and bound type heuristic algorithm was suggested by Civanlar, Grainger, Yin, and Lee[2], where a simple formula was developed for determination of change in power loss due to a branch exchange. Shirmohammdi and Hong [3] applied optimal power flow analysis to network reconfiguration for loss minimization. Baran and Wu [4] proposed an algorithm to identify branches to be exchanged using heuristic approach to minimize the search for selecting the switching options. Goswami and Basu [5] reported a heuristic algorithm that was based on the concept of optimum flow pattern. The optimum flow pattern with single loop formed by closing a normally open switch was found out, and this flow pattern was established in the radial network by opening a closed switch. This procedure was repeated until the minimum loss configuration was obtained .Lin, Chin and Yu [6] designed heuristic based switching indices by utilizing fuzzy notations for the distribution system loss reduction. Its solution scheme set up a decision tree which represented the various operations available, and a best-first search and heuristic rules were used to find feasible switching operations.

In this paper, a new heuristic search methodology is proposed for determining the minimum loss configuration of a radial distribution system. The proposed solution starts with initial configuration with all tie switches are in open position. The voltage differences across all tie switches and the two node voltages of each tie switch are computed using load flow analysis. Among all the tie switches, a switch with maximum voltage difference is selected first subject to the condition that the voltage difference is greater than the pre-specified value. The tie switch with the maximum voltage difference is closed and the sectionalize switches are opened in sequence starting from the minimum voltage node of the tie switch. The power losses due to each sectionalize switch are calculated and the opening sectionalize switches are stopped when the power loss obtained as previous sectionalizing is less than the current one. As the power loss due other sectionalize switches is more than the current, it is not necessary to open the sectionalize switches further in the loop. Based on the above procedure, the best switching combination of the loop is noted. The same procedure is repeated to all the remaining tie switches. This procedure favors the solution with a fewer switching operations. Another advantage with the algorithm is that the number of load flow computations is less and subsequently the computational effort is drastically reduced. The proposed algorithm is tested on a 106-bus system.

2. DISTRIBUTION SYSTEM LOSSES REDUCTION:

In recent years, there has been a continuous need to accommodate higher loads and overcome delays in the construction of new generating facilities arising from environmental concerns and higher investment costs. Distribution systems have been reported over the years and these will be critically reviewed.

There are three basic methods to reduce system losses in the distribution system:

- Reduce the equivalent resistance.
- The placement of compensating capacitors .
- Network reconfiguration .

3. PROBLEM FORMULATION OF POWER FLOW ANALYSIS:

The principal information obtained from the power flow analysis is the magnitude and phase angle of the voltage at each bus, and the real and reactive power flowing in each line. One of the main sources of losses is the copper losses in the distribution system in power overhead lines and cables since these losses are a function of current flows through the lines. These losses can also be reduced by network reconfiguration. One radial distribution systems in Naypyitaw city which is chosen as a case study area has many industrial loads, commercial loads, other departments and residential loads. Loss reduction is necessary for these systems because they have industrial zones and these locations are more power loss than other locations. ETAP is applied for load flow calculations of before and after reconfiguration states. This allows the proper layout for the distribution feeders in township to be made in the form of single line diagram which enables a better understanding the loss calculation of the location in a more precise way.

In power flow analysis of case study, the ratings of all equipments are chosen by International Electrotechnical Commission (IEC) standard at 50Hz in ETAP [6]. The load flow solutions for methods in branch exchange method are needed to manage optimal switching configuration of test systems. Real power, reactive power and volt drop of each bus are calculated by using Newton Raphson method for load flow solutions. It is more suitable for large scale of power system because it is more practical and efficient.

The power flow equations are the following:

Load Flow: $F(x, u) = 0$

$$P_{in} = \sum_{j=1}^{N_B} \left|Y_{ij} V_{i,n} Vj, n\right| \cos\left(\vartheta_{ij} + \delta_{j,n} - \delta_{i,n}\right) \quad (1) \quad Q_{in} = \sum_{j=1}^{N_B} \left|Y_{ij} V_{i,n} Vj, n\right| \sin\left(\vartheta_{ij} + \delta_{j,n} - \delta_{i,n}\right) \quad (2)$$

Where,

P_{in} = Real Power at Bus i
Q_{in} = Reactive Power at Bus i
$V_{i,n}$ and $V_{j,n}$ = Line Voltages
$\delta_{j,n}, \delta_{i,n}$ = Line Angles at the Line i and j
n = The Total Number of Branches in the Distribution System

Bus Voltage Constraint: $V_{min} \leq V \leq V_{max}$

The total power loss of feeders may then be determined by summing up the losses of all line sections of the feeder which is:

$$P_{PeakLoss} = \sum_{min=1}^{K} \left|I_{min}\right|^2 \times R_{min} \quad (3) \quad Q_{PeakLoss} = \sum_{min=1}^{K} \left|I_{min}\right|^2 \times X_{min} \quad (4)$$

Where,

I_{min} = Current through in the branch (m, n)
R_{min} = Resistance in the branch (m, n)
X_{min} = Reactance in the branch (m, n) [1]

4. OVERVIEW OF 106 - BUS RADIAL DISTRIBUTION NETWORK:

Pyinmana city is one of the large load centers in Myanmar. The distribution system under study is 11 kV distribution networks controlled by Naypyitaw Electricity Supply Board (NESB). Power transformer ratings and the values of power factor are 10 MVA with 0.8 (lagging) and incoming line is 33 kV with 120 mm^2 conductor. Outgoing lines are 11 kV and conductor size is 95 mm^2. ACSR conductor type is used for both 33 kV and 11 kV line. The distribution system is the overhead AC radial distribution system. The single line diagram of 106-Bus distribution system under study is shown in Fig. The total numbers of connected transformers and total connected capacities for each feeder is also shown in Fig.

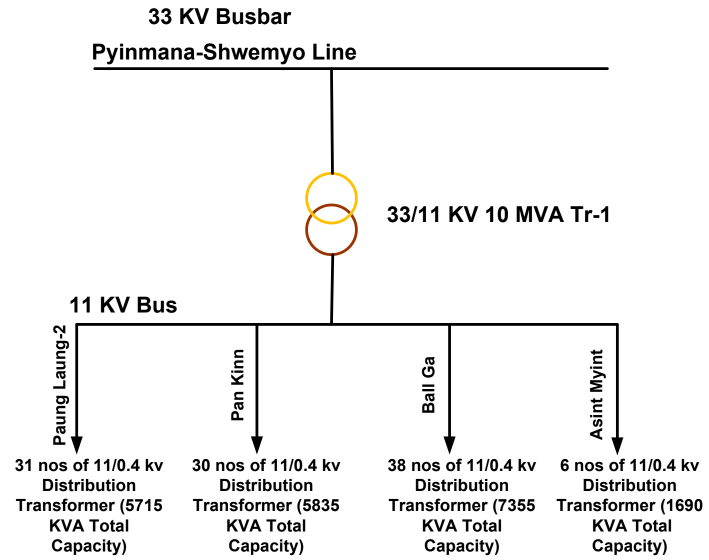

Figure 1. Single Line Diagram of 10MVA Power Transformer

The distribution network under study is located in Pyinmana Township in Naypyitaw, capital of Myanmar. Incoming line is connected to 33 kV Pyinmana-Shwemyo line and there are four numbers of 11 kV outgoing feeders as shown in Fig 1. In the distribution substation, 10 MVA, 33/ 11 kV step down transformer is employed for voltage level transformation. Therefore, the distribution voltage of the system under study is 11 kV. Total connected capacities of transformers for Paung Laung-2, Pan Kinn, Ball Ga and Asint Myint feeders are 5715 kVA, 5835 kVA, 7355kVA and 1690 kVA.

5. ALGORITHM USED IN THE HEURISTIC BRANCH EXCHANGE METHOD (HBEM):

The algorithm used in heuristic branch exchange method (HBEM) involves the following steps:

Method

STEP-1. Read the system input data;
STEP-2. Run the load flow program for the radial distribution network;
STEP-3. Compute the Power loss and voltage at various nodes;
STEP-4. Compute the voltage difference across the open tie switches (i.e., $\Delta Vtie(i)$, for i=1, 2, . . . , $Ntie$). $Ntie$ represents the total number of tie switches;
STEP-5. identify the open tie switch across which the voltage difference is maximum and its code p (i.e., $\Delta Vtie,max = \Delta Vtie(p)$);
STEP-6. Pick the two nodes of the tie switch p and check the node which has the minimum voltage, let it be Vx;
STEP-7. close the tie switch p to form the loop and open the sectionalize switch q (to retain radiality) adjacent to Vx. Then, calculate the power loss and store it in PLq;
STEP-8. Now close current sectionalize switch q and open the next adjacent sectionalize switch q+1 in that loop and calculate the power loss and store it in $PLq+1$;
STEP-9. If $PL,q - PL,q+1 < 0$, the optimal branch opening in that loop is the sectionalize switch adjacent to node Vx; Otherwise, swap $(PL,q, PLq+1)$ go to step 8
STEP-10. If the number of iterations (n) is less than or equal to number of tie switches ($Ntie$), set n as n+1 and go to step 2 to repeat the program for the rest of the tie switches;
STEP-11. Run the load flow and the print the results;
STEP-12. Check the configuration of the distribution system whether the closing of any remaining tie switch will found loop configuration or not. It so, stop the simulation and if not, go to step 2.
STEP-13. Stop.

6. SIMULATION RESULTS OF HBEM RECONFIGURATION:

The distribution network presented is used to demonstrate the validity and effectiveness of the HBEM reconfiguration. The HBEM reconfiguration for selected distribution system is simulated by using ETAP 12.6 software. The distribution network for reconfiguration consists of 106- buses and 6 tie lines; the total loads are 7500.00 kW and 6400.00 kVAr. The normally open switches are 107, 108, 109, 110, 111 and 112 represented by the dotted lines and sectionalizing switches are represented by the solid lines as shown in Fig 2.

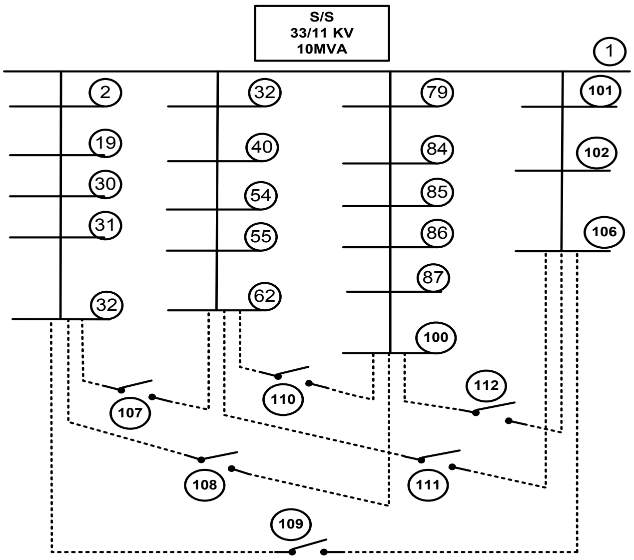

Figure 2. 106-Bus Initial Configuration of the Radial Distribution System

For this base case, the initial loss before reconfiguration is 811.2 kW. Among four 11 kV distribution feeders, the line parameters and load data for Paung Laung-2 Feeder are shown in Table I.

TABLE I
Network Data for 106 – Bus System

Line No.	From Bus	To Bus	R (Ω)	X (Ω)	Load at receiving End Bus	
					Real Power Load (kW)	Reactive Power Load (kVAR)
1	1	2	1.5224	0.7626	44.71	37.78
2	2	3	0.0677	0.0339	98.89	83.57
3	3	4	0.0594	0.0297	55.75	47.11
4	4	5	0.0844	0.0423	191.48	161.79
5	5	6	0.0760	0.0381	66.79	56.44
6	6	7	0.0844	0.0423	90.39	76.38
7	7	8	0.1354	0.0678	153.23	129.48
8	8	9	0.0932	0.0467	91.08	76.96
9	9	10	0.0844	0.0423	21.04	17.78
10	10	11	0.1016	0.0509	19.32	16.32
11	11	12	0.0844	0.0423	35.19	29.74
12	12	13	0.0899	0.0450	63.48	53.64
13	13	14	0.0932	0.0467	14.15	11.95
14	14	15	0.0844	0.0423	12.42	10.49
15	15	16	0.0932	0.0467	21.39	18.07
16	16	17	0.0760	0.0381	98.67	83.38
17	17	18	0.0677	0.0339	144.54	122.13
18	18	19	0.0594	0.0297	42.44	35.86
19	19	20	0.0760	0.0381	77.97	65.88
20	20	21	0.0844	0.0423	35.54	30.02
21	21	22	0.0760	0.0381	51.34	43.38
22	22	23	0.0677	0.0339	143.18	120.98

23	23	24	0.1693	0.0848	25.19	21.28
24	24	25	0.0677	0.0339	21.74	18.37
25	25	26	0.0844	0.0423	25.53	21.57
26	26	27	0.0844	0.0423	28.98	24.49
27	27	28	0.0760	0.0381	102.15	86.32
28	28	29	0.0677	0.0339	113.02	95.50
29	29	30	0.0644	0.0322	39.33	33.23
30	30	31	0.0710	0.0356	42.78	36.15
31	31	32	0.0727	0.0364	138.69	117.19

The voltage differences across all tie switches are computed for the network shown in Fig 2 and are shown in Table II. It is observed that the maximum voltage difference occurs across the tie switch 112. Hence, the tie switch 112 is closed first as the voltage differences across the remaining tie switches are smaller in magnitude.

TABLE II
Voltage Difference Across All Open tie Switches after First Switching

Sr. No	Tie Switch Number	Voltage Difference Across Tie Switch (pu)
1	107	0.02227
2	108	0.02345
3	109	0.05736
4	110	0.00181
5	111	0.07964
6	**112**	**0.08082**

Now, if the tie switch 112 is closed, a loop will be formed and total number of branches including tie branch in the loop will be 100. These branches are 38 number on the Ball Ga feeder, 6 number on Asint Myint feeder and the tie line branch. Opening of each branch in this loop is an option. However, opening of some of the branches causes the violation of the constraints and gives the infeasible solution. In addition, opening of all branches in the loop in sequence order or in any another order increases the computational burden. In this algorithm, sectionalized branches are opened (to retained the radiality) either left or right of the selected tie switch based on the minimum voltage node of the tie switch. This procedure is explained as follows.

The two node voltages connected to tie switch 112 are evaluated and the smaller node voltages is noted. In this case, the smaller node voltage of the tie switch 112 is occurred at node 100. Therefore, one branch at a time in the loop is opened starting from the branch between node 100and node 99. Then the power loss due to each objective is obtained till the power loss ($PLq+1$) as current objective is greater than the previous objective (PLq). In this loop, the first sectionalized branch (100-99) is opened as it adjacent to the node 90 and power loss is computed and shown in Table VI. In same manner, next adjacent sectionalize branches 99-98, 98-97, 97-96, and 96-95 are opened one at a time in sequence and power loss is computed and shown in the Table VI. As the power due to sectionalized branch 75-74 is greater than 86-85, the optimal opening branch in the loop is between the nodes 86 and 85. Further opening of the branches beyond the branch 85-84 in the loop is giving either more power loss than the minimum already obtained at the branch 86-85 or infeasible solution. Hence, the opening of the remaining branches 85-84, 84-83, 83-82, 82-81, 81-80, 80-79, 79-78, 78-77, 77-76, 76-75, 75-74, 74-73, 73-72, 72-71, 71-70, 70-69, 69-68, 68-67, 67-66, 66-65, 65-64, 64-63 and 63-62 are discarded. The optimal radial loop for the first switching operation is obtained by closing the tie switch 112 and opening the branch between the nodes 86 and 85. The advantage of this procedure is that it is not necessary to visit all the sectionalizing switches in the loop. Therefore, the search space of sectionalizing switches in the loop is drastically reduced. For the second switching operation, the voltage difference across remaining tie switches (discarding tie switch 112) is computed and the simulation results are shown in Table III.

TABLE III
Voltage Difference Across the Tie Switches after Second Switching

Sr. No	Tie Switch Number	Voltage Difference Across Tie Switch (pu)
1	107	0.02236
2	108	0.02527
3	109	0.02745
4	110	0.04764
5	**111**	**0.04982**

From Table III, it is observed that the maximum voltage difference occurs across the tie switch 111. The smaller node voltage aside of the tie switch 111 is occurred at node 62. Repeating the same procedure as in case of tie switch 112, the optimal radial configuration for the second switching operation is obtained by closing the tie switch 111 and opening the sectionalized branch between the nodes 55 and 54.

Among the remaining tie switches 107, 108, 109 and 110, the voltage difference across the tie switch 109 is greater than other three tie switches as shown in Table IV. Therefore, the tie switch 109 is selected for the third switching operation. The smaller node voltage aside of tie switch 109 is occurred at node 32. Repeating the same procedure as in cases of tie switch 112 and 111, the optimal radial configuration for third switching operation is obtained by closing the tie switch 109 and opening the sectionalized branch between the nodes 31 and 30.

TABLE IV
Voltage Difference across the Tie Switches after Third Switching

Sr. No	Tie Switch Number	Voltage Difference Across Tie Switch (pu)
1	107	0.01209
2	108	0.01091
3	**109**	**0.01309**
4	110	0.00118

The voltage difference across the remaining three tie switches 107, 108 and 110 are shown in Table V. The closing of the remaining tie switches will cause the loop connection. Thus, radial reconfiguration cannot be maintained. Therefore, the closing of tie switches 107, 108 and 110 are discarded in the simulation. Under this condition, all loads are connected to the system and the distribution system is still maintaining in radial configuration.

TABLE V
Voltage Difference across the Tie Switches after Forth Switching

S. No	Tie Switch Number	Voltage Difference Across TieSwitch (pu)
1	107	0.00064
2	108	0.00182
4	110	0.00118

TABLE VI
Simulation Results for Total Power Losses in Distribution System with HBEM Reconfiguration

Tie Switch (Closed)	Smaller Node Voltage Aside of the Tie Switch	Sectionalize Switch Open Between Nodes	Power Loss (kW)
112	100	100-99	795.2
		99-98	786.8
		98-97	777.9
		97-96	772.2
		96-95	755.0
		95-94	749.9
		94-93	742.0
		93-92	739.6
		92-91	735.5
		91-90	732.2
		90-89	724.9
		89-88	721.2
		88-87	720.7
		87-86	**720.4**
		86-85	723.2
111	62	62-61	708.7
		61-60	704.3
		60-59	700.8
		59-58	695.9
		58-57	691.5
		57-56	690.2
		56-55	688.0
		55-54	**686.8**
		54-53	688.8

109	32	32-31 **31-30** 30-29	683.5 **683.3** 683.5

The optimal radial configuration of the network after all the switching operations is shown in figure 3. Table VII shows the simulation results of the base configuration and the optimal configuration with HBEM method. The power loss before reconfiguration is 811.2 kW and after reconfiguration with HBEM method is 683.3 kW. From the results, it is observed that reduction in power loss is 127.9 kW which is approximately 15.77 %. For the entire process, it is needed to run the number of load flow 24 times.

The bus voltages in the distribution system with before reconfiguration and after HBEM reconfiguration are depicted in figure 4. It is observed that the minimum voltage before reconfiguration is 0.912 p.u and after HBEM reconfiguration is 0.936 p.u. This shows that the minimum voltage in the network is improved by 2.4 % after HBEM reconfiguration.

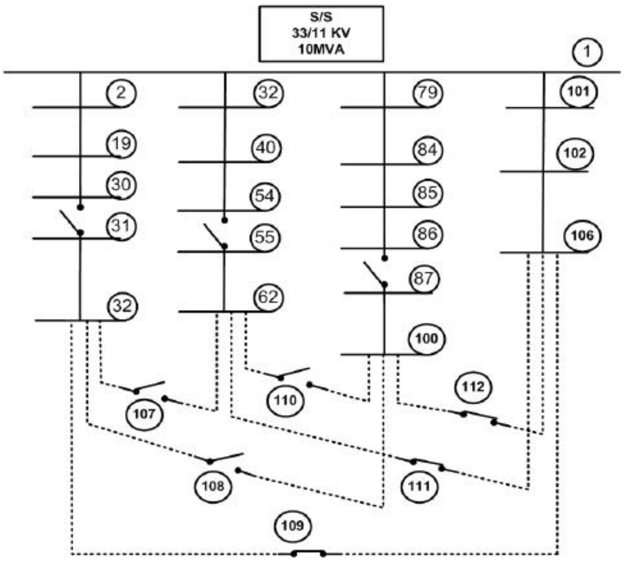

Figure 3. 106-Bus final radial configuration of distribution system with HBEM

TABLE VII
Simulation Results with HBEM reconfiguration

	113-bus Test System
Loss in the base reconfiguration	811.2 kW
Loss in the optimal reconfiguration	683.3 kW
Loss reduction	127.9 kW
Loss reduction	15.77
Number of load flow	24

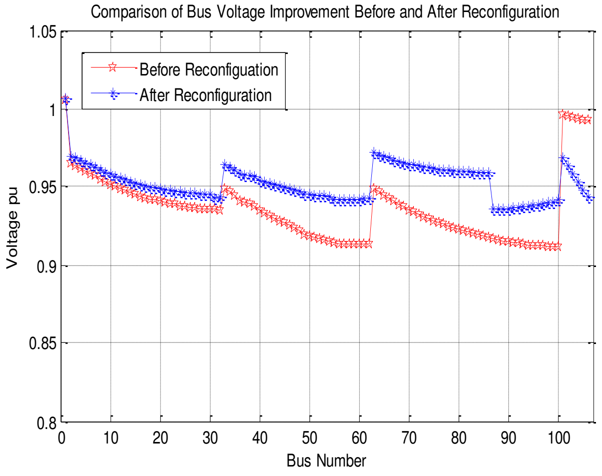

Figure 4. Comparison of bus voltage improvement before and after Reconfiguration with HBEM Method

7. ALGORITHM OF PROPOSED IMPROVED BRANCH EXCHANGE METHOD (IBEM) FOR EXTENDED RECONFIGURATION:

The application of HBEM reconfiguration to distribution system can reduce total power losses and can improve system bus voltages. According to the simulation results, the bus voltages and current (and power) flows on the branches are altered whenever the opening section is vary. The detailed study on the voltage across the first sectionalizing switch (i.e. sectionalizing switch between bus 86 and bus 87) is executed and the results are obtained as follow.

After the closing of the tie switch 112 and opening of sectionalizing switch between bus 86 and 87, the voltage across the switch under study is 32 V. This voltage is smaller than the voltages across all remaining tie switches and larger than tie switch 112. Then tie switch 111 is closed and sectionalizing switch between bus 54 and bus 55 is opened. Under this condition, the voltage across the switch under study becomes 191 V. In final step of HBEM, the tie switch 109 is closed and sectionalizing switch between bus 30 and bus 31 is opened. Under this condition, the voltage across the switch under study become 257 V. This voltage is larger than all opening tie switches and other sectionalizing switches.

According to the study, it is observed that opening of section 86-87 on feeder 3 is the best choice for loss reduction in closing of first tie switch. After closing tie switches 111 and 109 and opening section 54-55 on feeder 2 and section 30-31 on feeder 1, the large voltage difference on opening of section 86-87 indicates that this opening is no longer the best choice on feeder 3. The opening of adjacent section connected to the bus with smaller voltage can reduce the voltage across the opening and total power losses in the distribution system. According to this finding, the power losses provided by HBEM reconfiguration are not minimum power loss in the system. The power losses can be still reduced by executing the following extended algorithms.

STEP-1. Compute the voltage difference across the sectionalizing switches (i.e., $\Delta Vssw(i)$, for i=1, 2, . . . , $Nssw$). $Nssw$ represents the total number of sectionalizing switches;

STEP-2. identify the open sectionalizing switch across which the voltage difference is maximum and its code m (i.e., $\Delta Vssw,max= \Delta Vssw(m)$);

STEP-3. Pick the two nodes of the sectionalizing switch m and check the node which has the minimum voltage, let it be Vy;

STEP-4. close the sectionalizing switch m to form the loop and open the sectionalize switch n (to retain radiality) adjacent to Vy. Then, calculate the power loss and store it in PLn;

STEP-5. Now close current sectionalize switch n and open the next adjacent sectionalize switch n+1 in that loop and calculate the power loss and store it in $PLn+1$;

STEP-6. If $PL,n - PL,n+1 < 0$, the optimal branch opening in that loop is the sectionalize switch adjacent to node Vy; Otherwise, swap $(PL,n, PLn+1)$ go to step 5

STEP-7. If the number of iterations is less than or equal to number of open sectionalizing switches ($Nssw$), go to step 1 to repeat the program for the rest of the sectionalizing switches;

STEP-8. Run the load flow and the print the results;

STEP-9. Check the configuration of the distribution system for radial configuration.

STEP-10. Stop.

8. Simulation Results with IBEM:

For the execution of IBEM reconfiguration, the voltage differences across all opened sectionalizing switches are computed for the network shown in fig. 3 and the simulation results are shown in Table VIII. It is observed that the maximum voltage difference occurs across the Sectionalizing switch 86-87.

TABLE VIII
Voltage Difference Across All Opened sectionalizing Switches After HB EM reconfiguration

Sr. No	Sectionalizing Switches	Voltage Difference Across Opened Sectionalizing Switch (pu)
1	30-31	0.00236
2	54-55	0.00218
3	**86-87**	**0.02336**

The two node voltages connected to Sectionalizing switch 86-87 are evaluated and the smaller node voltage is noted. In this case, the smaller node voltage of the Sectionalizing switch 86-87 is occurred at bus 87. Therefore, one branch at a time in the loop is opened starting from the branch between node 87-88, 88-89, 89-90, etc and the resulting power losses are recorded.

TABLE IX
Voltage Difference Across All opened sectionalizing Switches After First sectionalizing Switch is relocated

Sr. No	Sectionalizing Switches	Voltage Difference Across Tie Switch (pu)
1	30-31	0.00572
2	**54-55**	**0.00572**
3	89-90	0.00191

After finding new location of opening section on feeder 3, the same procedure is executed for feeder 2 and feeder 1. For feeder 2, the two node voltages connected to Sectionalizing switch 54-55 are evaluated and the smaller node voltages is noted. In this case, the smaller node voltage of the Sectionalizing switch is occurred at bus 54. Therefore, one branch at a time in the loop is opened starting from the branch between nodes 54-53 and then 53-52.

TABLE X
Voltage Difference Across All Opened sectionalizing Switches After second sectionalizing Switch is relocated

Sr. No	Sectionalizing Switches	Voltage Difference Across Tie Switch (pu)
1	**30-31**	**0.02227**
2	54-53	0.02345
3	89-90	0.05736

For the relocation of sectionalizing switch on feeder a, the two node voltages connected to Sectionalizing switch 30-31 are evaluated and the smaller node voltages is noted. In this case, the smaller node voltage of the Sectionalizing switch is occurred at bus 30. Therefore, one branch at a time in the loop is opened starting from the branch between nodes 31-32 and then 30-31.

TABLE XI
Voltage Difference Across All Opened Sectionalizing Switches After Third Sectionalizing Switch Is Relocated

Sr. No	Sectionalizing Switches	Voltage Difference Across Tie Switch (pu)
1	29-30	0.00145
2	53-54	0.00727
3	89-90	0.00690

With the application of IBEM method, the optimal radial configuration of the network with new locations of opened sectionalizing switches is obtained as shown in figure 5. Table XII shows the simulation results of new total power losses with IBEM reconfiguration. According to the simulation results, the total power losses of 683.3 kW from HBEM reconfiguration is reduced to 674.8 kW with IBEM reconfiguration. For the entire process of IBEM reconfiguration, it is needed to run the number of load flow 8 times and power losses is reduced by 8.5 kW.

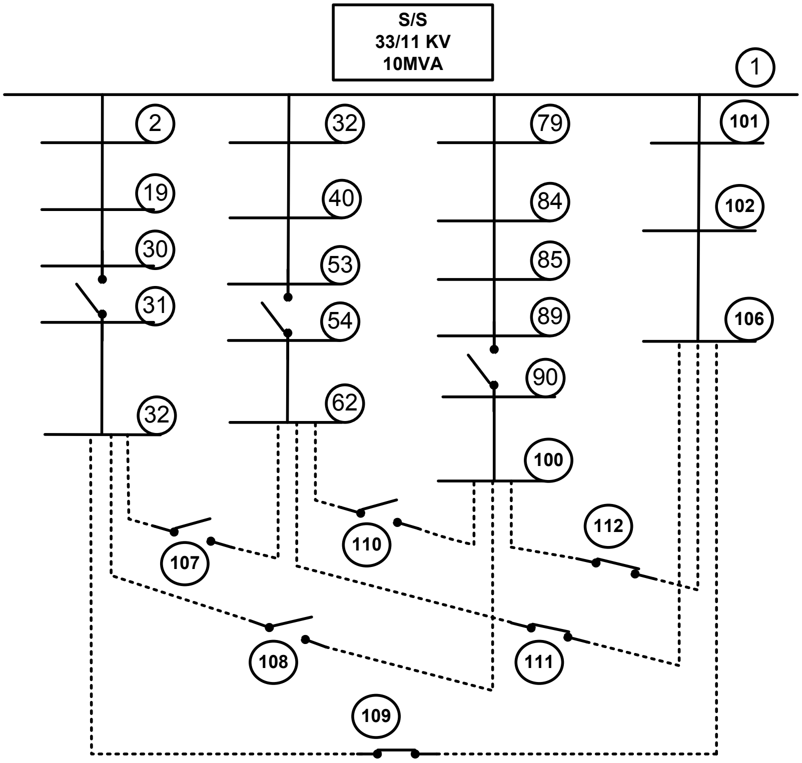

Figure 5. 106-Bus final radial configuration of distribution system with IHBEM

TABLE XII
Simulation Results for Total Power Losses in Distribution System with HBEM Reconfiguration

Sectionalizing Switch (Closed)	Smaller Node Voltage Aside of the Tie Switch	Sectionalize Switch Open Between Nodes	Power Loss (kW)
112	86-87	86-87	683.3
		87-88	678.8
		88-89	677.7
		89-90	**675.7**
		90-91	676.8
111	55-54	55-54	675.7
		54-53	**675.0**
		53-52	675.6
109	32-31	30-31	675.0
		29-30	**674.8**
		29-28	676.0

9. PERFORMANCE COMPARISON FOR TWO ALGORITHMS:

To observe the performance of the proposed IBEM reconfiguration, the measurements are carried out for real power losses, reactive power losses and bus voltages for original radial system, radial system obtained by branch exchange method and radial system obtained by improved method.

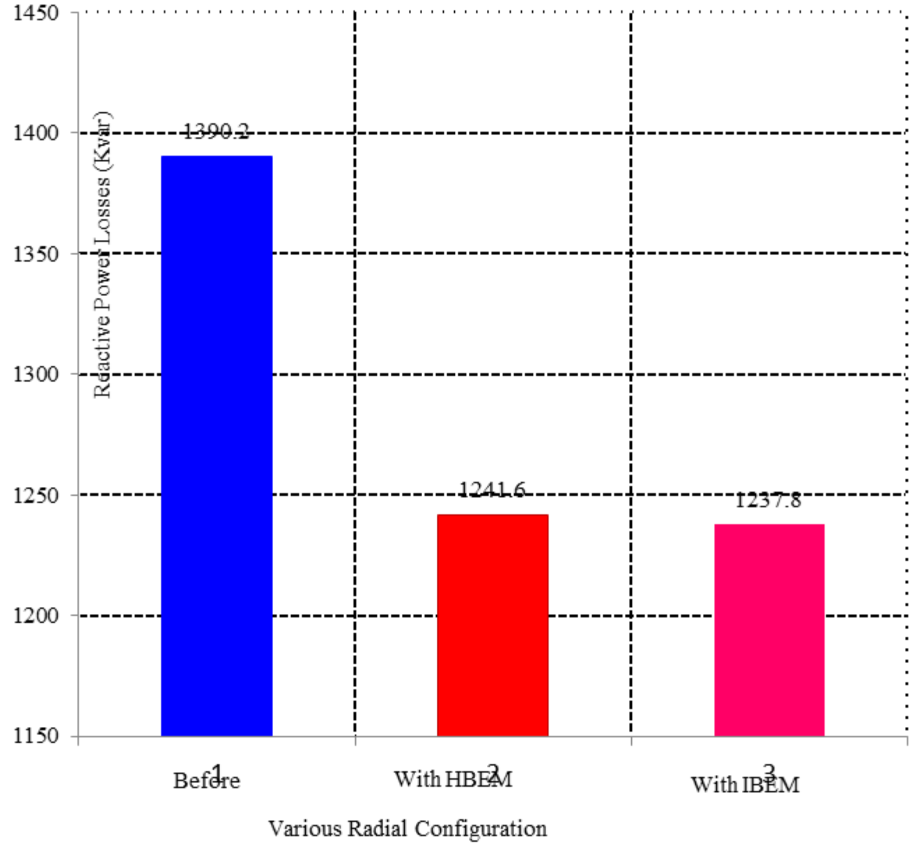

Figure 6. Real Power Losses Comparison for 106 Buses Radial Distribution System

Real power losses comparison for 106 buses radial distribution system is shown in Fig 6. According to the measurement, real power losses are 811.2 kW, 683.3 kW and 674.8 kW for original system, with branch exchange method and with improved branch exchange method respectively. The real power losses reduction by HBEM is 15.77 % and with proposed improved branch exchange method is 16.81%. With the improvement of branch exchange method, 8.5 kW of additional real power losses is reduced compared to HBEM. This reduction in power losses is correspond to saving MMK 41.82 million annually.

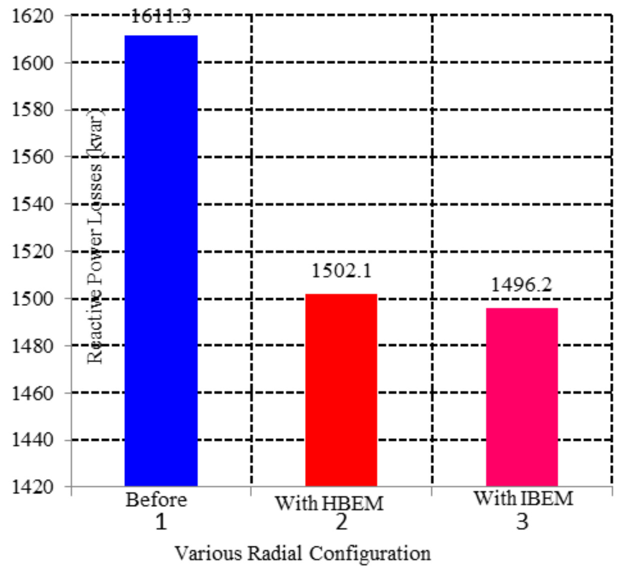

Figure 7. Reactive Power Losses Comparison for 106 Buses Radial Distribution System

Reactive power losses comparison for 106 buses radial distribution system is shown in Fig 7. According to the measurement, reactive power losses are 1611.3 kVAR, 1502.1 kVAR and 1497.4 kVAR for original system, with branch exchange method and with improved branch exchange method respectively. The reactive power losses reduction by HBEM is 6.78 % and with proposed improved branch exchange method is 7.07 %. With the improvement of branch exchange method, 4.7 kVAR of additional reactive power losses is reduced compared to HBEM.

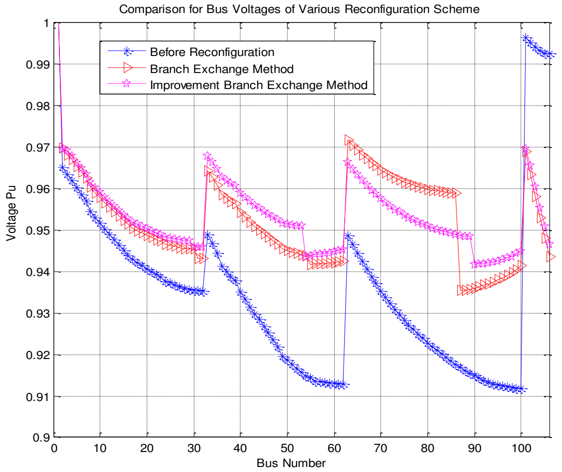

Figure 8. Comparison of Bus Voltages for 106 Bus Radial Distribution System

Bus voltage comparison for 106 buses radial distribution system is shown in Fig 8. According to the measurement, minimum bus voltage magnitudes are 10.03 kV, 10.291 kV and 10.358 kV for original system, with branch exchange method and with improved branch exchange method respectively. Thus minimum bus voltage can be improved by the proposed method. The voltage regulation of the system is improved to 6.44 % with HBEM reconfiguration and 5.84 % with proposed method. Therefore, the proposed improved branch exchange method can offer better distribution system performance.

10. CONCLUSION:

In this paper, the reconfiguration of distribution network by improved branch exchange method is presented. To obtain better distribution system performances than heuristic branch exchange method, the improvement algorithm is explored in this paper. To analyze the performance of the propose system, various simulations are carried out for 106 buses distribution system. According to simulation results, the improved branch exchange method, additional real power losses can be reduced compared to heuristic branch exchange method. In case of system bus voltages, the propose system can provide better voltage regulation. Therefore, the proposed improved branch exchange method can be effectively applied in real time application of the large distribution system under widely varying load conditions for better distribution system performances.

ACKNOWLEDGMENT:

The author is especially indebted and grateful to supervisor Dr. Myint Thuzar, Professor, Department of Electrical Power Engineering, Mandalay Technological University, for her encouragement, patience and valuable supervision, suggestions, kind permission and guideline during the entire course for the preparation of this paper. The author would like to express her thanks and to all her teachers from Mandalay Technological University.

REFERENCES:

1. S.Naveen, K.S.Kumar and K.Rajalakshmi, "Distribution system reconfiguration for loss minimization using modified bacterial foraging optimization algorithm" International Journal of Electrical Power and Energy Systems, vol. 69, pp. 90-97 , 2015.
2. D.Das, "A fuzzy multi objective approach for network reconfiguration of distribution systems," IEEE Transactions on Power Delivery, vol.21, no.1, pp. 201-208,2006.
3. G.K.V. Raju and P.R. Bijwe, " Efficient reconfiguration of balanced and unbalanced distribution systems for loss minimization" IET Generation Transmission Distribution, vol.2,no.1, pp. 7-12, 2008.
4. D.S. Rani, M.Subrahmanyam and N.Sydulu, "Multiobjective invasive weed optimization-an application to optimal network reconfiguration in radial reconfiguration systems" International Journal of Electrical Power and Energy Systems, vol. 73, pp. 932-942 , 2015.
5. J.A. Martin and A.J. Gil, " A heuristic approach for distribution loss reduction" Electric Power System Research, vol. 78, pp. 1953-1958, 2008.
6. S.Mishra, D.Das and S.Paul, "A simple algorithm for distribution system load flow with distributed generaion" *Proc. IEEE ICRAIE,* Jaipur, India, pp.1-5, 2014.
7. S.Mishra, D.Das and S.Paul, "A simple algorithm to implement active power loss allocation schemes in radial distribution systems" Journal of Institute of Engineers(India), Series- B, vol. 93, no.3, pp. 223-232, 2012.
8. S.Civanlar, J.J.Grainger, H.Yin, and S.S.H. Lee, "Distribution feeder reconfiguration for loss reduction," IEEE Transactions on Power Delivery, vol.3, no.3,pp. 1217-1223,1988.
9. J.P.Chiou, C.F.Chang and C.T.Su, "Variable scaling hybrid differential evolution for solving network reconfiguration of distribution systems" IEEE Transactions on Power Systems,vol.20, no.2, pp. 668-674, 2005.
10. F.V.Gomes, S.Carneiro Jr., J.L.R.Pereira, M.P.Vinagre, P.A.N. Garcia and L.R.Araujo, "A new heuristic reconfiguration algorithm for large distribution systems" IEEE Transactions on Power Systems,vol.20,no.3, pp.1373-1378, 2005.
11. F.V.Gomes, S.Carneiro Jr., J.L.R.Pereira, M.P.Vinagre, P.A.N. Garcia and L.R.Araujo, "A new distribution system reconfiguration approach using optimal power flow and sensivity analysis" IEEE Transactions on Power Systems,vol.21,no.4, pp.1616-1622, 2006.
12. E.M.Carreno, R. Romero and A. Padilha-Feltrin, "An efficient codification to solve distribution network reconfiguration for loss reduction Problem" IEEE Transactions on Power Systems,vol.23,no.4, pp.1542-1551, 2008.
13. C.Wang and Y.Gao, " Determination of power distribution network configuration non revisitng genetic algorithm" IEEE Transactions on Power Systems,vol.28,no.4, pp.3638-3648, 2013.
14. E.J. Oliveira, G.J. Rosseti, L.W. Oliveira, F.V. Gomes and W. Peres, "New algorithm for reconfiguration and operating procedures in electric distribution systems" Electrical Power and Energy Systems, vol. 57, pp. 129-134 , 2014.
15. B.Enacheanu, B.Raison, R.Caire, O.Devaux, W.Bienia and N.Hadjsaid, "Radial network reconfiguration using genetic algorithm based on Matroid theory" IEEE Transactions on Power Systems,vol.23,no.1,pp.186-194,2008.
16. H.D.Macedo-Braz and B.A.DeSouza, "Distribution network reconfiguration using genetic algorithms with sequential Encoding: subtractive and additive approaches" IEEE Transactions on Power Systems,vol.26, no.2,pp.582-593, 2011.
17. A.J.G. Mena and J.A.M. Garcia, " An efficient heuristic algorithm for reconfiguration based on branch power flows direction" International Journal of Electrical Power and Energy Systems, vol. 41, pp. 71-75, 2012.
18. H.Ahmadi and J.R.Marti, "Minimum loss network reconfiguration: a minimum spanning tree problem" Sustainable Enegy, Grids and Networks, vol.1, no.1,pp.1-9,2015.
19. A.M.Imran, M.Kowsalya and D.P.Kothari, "A novel integration technique for optimal network reconfiguration and distributed generation placement inpower distribution networks" International Journal of Electrical.