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Power Distribution System Reconfiguration for Loss Reduction By using Heuristic Method

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Abstract: Power Distribution system consists of tie and sectionalizing switches. Tie switches are normally open and sectionalizing switches are normally close. Reconfiguration can be used for the objectives of loss reduction, load balancing, etc. The change in network configuration is performed by opening sectionalizing (normally closed) and closing tie (normally open) switches of the network. Inputs data are based on real time data collected from 66/11kV substations under Yangon Electricity Supply Board (YESB). The proposed method is tested on 90-Bus, overhead AC radial distribution network of North Dagon Township (BaeLi substation), Yangon, Myanmar. The distribution network for existing and reconfiguration conditions are simulated by MATLAB software. This paper is focusing on evaluating the power loss reduction.

Keywords: radial distribution system, network reconfiguration, load flow analysis, loss reduction, heuristics method, voltage profile improvement

1. INTRODUCTION

A power system consists of generation, transmission and distribution system. The electric power is transmitted and distributed to consumers over long distances at different voltage levels. A distribution system is meant to provide reliable power in cost effective manner to the consumers. A typical distribution system will consist of one or more distribution substations consisting of one or more “feeders”. The power demand is increasing at an alarming rate day by day. Power losses occur in the electric distribution system that are important issues for different classes of consumers. In the distribution system, there are different ways to decrease losses in the distribution system such as network reconfiguration, capacitor placement, distributed generation. The main aim of the distribution system reconfiguration is to get the optimal distribution scheme that gives minimum losses.

2. RADIAL DISTRIBUTION SYSTEM

Radial distribution system is generally used as it is very easy to operate, design and to place the protective devices. It is widely used in populated areas. A radial distribution system has only one power source for a group of customer radial feeders are characterized by having only one path for the power to flow from the source to each customer. The radial distribution system is employed when the power is generated at low voltage and the substation is located at the center of the load.

3. NETWORK RECONFIGURATION

Network reconfiguration is an important sub-problem of the overall distribution system. The main objective of distribution network reconfiguration is the appropriate configuration of switch operation. Basic concept of network reconfiguration is to attain at the best set of sectionalizing switches to be opened for a given set of tie switch such that the system performance. Feeder reconfiguration allows the transfer of loads from heavily- loaded feeders to relatively lightly- loaded feeders and from higher-resistance routes to lower resistance routes to obtain the least I^2R, where the resistance route is the total resistance from the source to the load point. Such transfers are effective not only in terms of altering the level of loads on the feeder being switched, and reducing the losses, but also in improving the voltage profile along the feeders and affecting reduction in the overall system power losses. Under normal operating conditions, distribution engineers periodically reconfigure the feeders by opening and closing switches (switching operation) in order to increase the network reliability and/or reduce line losses. The most important operational constraint for network reconfiguration problem is the radial nature of the network i.e., all loads must be energized and should not form a mesh loop structure which may endanger the entire system operation.

4. OVERVIEW OF 90-BUS RADIAL DISTRIBUTION NETWORK

The system under study is one of the 11 kV distribution networks under Yangon Electricity Supply Board(YESB). The distribution networks are located in North Dagon Township in Yangon. This study has been carried out MATLAB software. Figure 1 illustrates the schematic diagram of 90-Bus existing radial distribution system. Incoming line is 66kV and outgoing line is 11kV. Step down power transformer is used to distripute power and its rating is 20MVA. Installed capacities for Sayarsan, Station, U Wisara and Tabinshwehtee are 8.15 MVA, 0.93 MVA, 2.585 MVA and 10.07 MVA. To solve the network reconfiguration problem, all the tie and sectionalizing switches are considered as candidate switches. In this paper, the objective is to minimize the system power loss under a certain load pattern.

4.1 LOAD FLOW ANALYSIS

$$P_{peak\ loss} = \sum_{mn=1}^{k} |Imn|^2 \times Rmn \qquad (1)$$

$$Q_{peakloss} = \sum_{mn=1}^{k} |Imn|^{2} \times Xmn \quad (2)$$

$$I_{mn} = \frac{Pmn - Qmn}{Vmn} \quad (3)$$

Percentage change in the power loss reduction can be defined by:

$$\%\ PowerLoss = \frac{Plb - Pla}{Plb} \times 100 \quad (4)$$

where;
Imn = Current through in the branch (m, n)
Vm = Voltage at node m
Pmn = Real power through in the branch (m, n)
Rmn = Resistance in the branch (m, n)
Xmn = Reactance in the branch (m, n)
Pla = Power loss after reconfiguration
Qmn = Reactive power through in the branch (m, n)
Plb = Power loss before reconfiguration

The voltage magnitude at each bus must be maintained within limits.
$V_{i,min} \le V \le V_{i,max}$ for all PQ buses
V_i is voltage magnitude of bus i;

$V_{i,,min}$ and $V_{i›,max}$ are minimum and maximum voltage limits of bus.

Furthermore, the radial structure of network must be maintained, and all loads must be served.

The power flow equations are the following:
Load Flow: F(x, u) = 0

$$P_{i,n} = \sum_{j=1}^{N} |YijVi,nVj,n| \cos(\vartheta ij + \delta j,n \_ \delta i,n) \quad (5)$$

$$Q_{i,n} = -\sum_{j=1}^{N} |YijVi,nVj,n| \cos(\vartheta ij + \delta j,n \_ \delta i,n) \quad (6)$$

5. RECONFIGURATION BY HEURISTICS METHOD

In the existing radial distribution system, there are four lines before network reconfiguration because voltage reduction, long length and overloaded lines. Figure 1 illustrates the schematic diagram of 90-Bus existing radial distribution system. Reconfiguration is an indispensable method for loss reduction in power distribution network. This paper focus to optimize the power distribution process in the feeders and to improve the voltage profile improvement. The network reconfiguration process for loss reduction of the distribution network is given below:
Step (1) Read system data (P, Q, R, X);
Step (2) Run the load-flow program for distribution networks;
Step (3) Compute the voltage difference across the open tie switches (i.e., for i = 1,2, n-tie);
Step (4) Identify the open tie switch across which the voltage difference is maximum and its code k (i.e., $\Delta Vtiemax = \Delta V(k)$);
Step (5) If $\Delta Vtie\max \geq= \varepsilon$ go to Step (6); otherwise, go to Step10);
Step (6) Select the tie switch "k" and identify the total number of loop branches (Nk)
Step (7) Open one branch at a time in the loop and evaluate the loss by equation (3.1)
including the tie branch when the tie-switch "k" is closed;
Step (8) Obtain the optimal solution for the operation of tie-switch "k", (i.e., stop when the loss obtained by opening the current switch is greater than the previous one, i = 1, 2, …, Nk);
Step (9) Rearrange the coding of the rest of the tie switches and go to Step 2);
Step (10) Print output results;
Step (11) Stop.

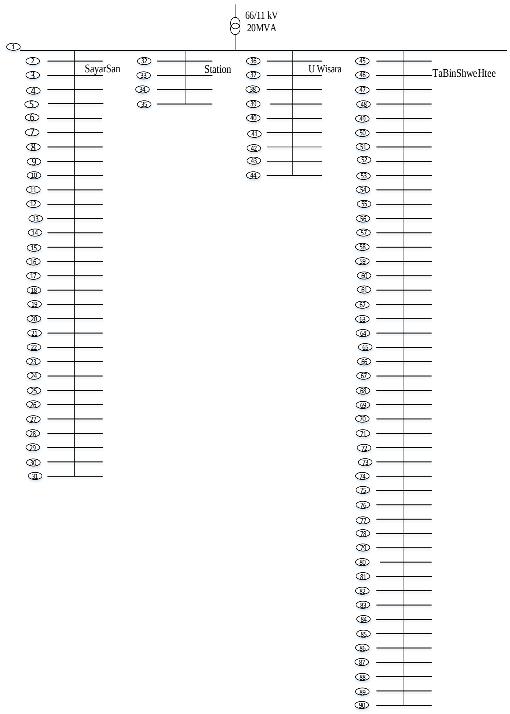

Figure 1. Single line diagram of 90-Bus system

Figure 2 shows the schematic diagram of 90-Bus existing radial distribution system. In this paper, the heuristics method is proposed with initial configuration and meshed topologies. By using MATLAB software, load flow solutions are simulated.

A heuristics technique for the reconfiguration of distribution networks is used to reduce their line losses under normal operating conditions. The proposed solution starts with initial configuration with all the tie switches are in open position. The voltage differences across all the tie switches and the two node voltages of each tie switch are computed applying load flow analysis for the network. 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 due to 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. Newton Raphson load flow has been used in the entire reconfiguration process. When the switching is performed, the network needs to be maintained in radial form. Figure 3 shows the connection of 90-Bus system with tie lines. Figure 4 shows the 90-Bus system final configuration.

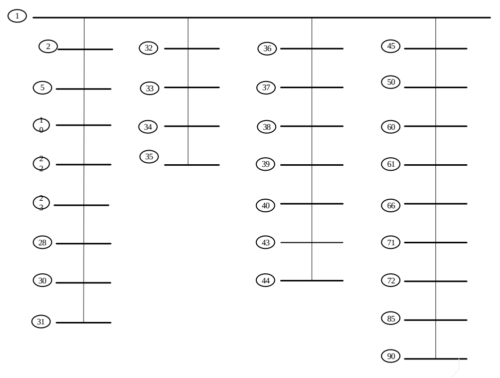

Figure 2. 90-Bus Existing radial system

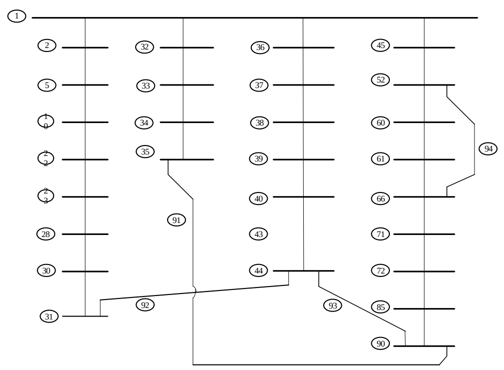

Figure 3. 90-Bus system with tie lines

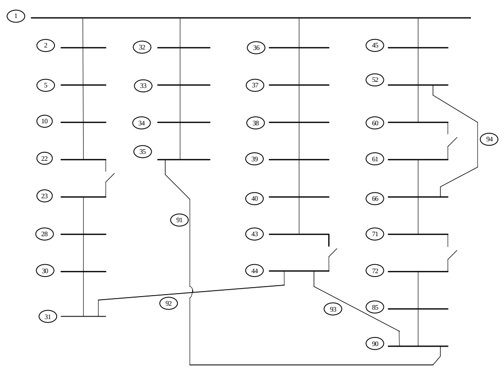

Figure 4.90-Bus system final configuration

6. SIMULATION RESULTS

The distribution network for reconfiguration consists of 90 buses and 4 tie lines. The voltage differences across all tie switches are computed for the network shown in Table I. It is occurred in the maximum voltage difference across normally open tie switch 92. Hence, the tie switch 92 is closed first as the voltage differences across the remaining tie switches are smaller in magnitude. Now, if the tie switch 92 is closed, a loop will be formed. Opening of each branch in this loop is an option. In this method, sectionalizing branches are opened (to remain the system radiality) either left or right of the selected tie switch based on the minimum voltage node of the tie switch.

Table I. Voltage difference across all open tie switches after first switching

S. No	Tie switch Number	Voltage difference across tie switch(pu)
1	91	0.3067
2	**92**	**0.3112**
3	93	0.2491
4	94	0.2601

This procedure is explained as follows. The two node voltages of tie switch 92 are evaluated and the minimum of two node voltages is noted. In this case, the minimum voltage of the tie switch 92 is 71. Therefore, one branch at a time in the loop is opened starting from the node 71 and the power loss due to each objective is obtained till the power loss (due to current objective is greater than the previous objective). In this loop, the first sectionalize branch (71-72) is opened as it adjacent to the node 71 and the power loss is computed and shown in Table V. In the same manner, next adjacent sectionalize branches (72-73) is opened and the power loss is computed and shown in Table V. As the power due to sectionalize branch 72-73 is greater than 71-72, the optimal opening branch in the loop is between the nodes 71 and 72. Further opening of the branches beyond the branch 72-23 in the loop, is giving either more power loss than the minimum already obtained at the branch 71-72 or infeasible solution. 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. The optimal radial loop for the first switching operation is obtained by closing the tie switch 92 and opening the branch between the nodes 71 and 72. For the second switching operation, the voltage difference across remaining tie switches are computed and shown in table II.

Table II. Voltage difference across all open tie switches after second switching

S. No	Tie switch Number	Voltage difference across tie switch(pu)
1	**91**	**0.0258**
3	93	0.0248
4	94	0.0219

The voltage difference across the remaining three tie switches 91, 93 and 94 are shown in Table II. Among the tie switches 91, 93 and 94, the voltage difference across the tie switch is greater than remaining two and it is observed that the maximum voltage difference occurs across tie switch 91. Therefore, the tie switch 91 is selected for the second switching operation as voltage difference is greater than the specified value. The minimum voltage of the tie switch 91 is 22. Repeating the same procedure as in case of tie switch 92, the optimal radial configuration for the second switching operation is obtained by closing the tie switch 91 and opening the sectionalizing branch 22 and 23.

From table III, tie switch 93 is selected for the third switching operation as voltage difference. Repeating the same procedure as in case of tie switch 91. The optimal radial configuration for the third switching operation is obtained by closing the tie switch 93 and opening the sectionalizing branch 43 and 44.

Table III. Voltage difference across all open tie switches after third switching

S. No	Tie switch Number	Voltage difference across tie switch (pu)
3	**93**	**0.3474**
4	94	0.3073

For fourth switching operation tie switch 94 is considered as the maximum voltage difference. The optimal radial configuration for the fourth switching operation is obtained by closing the tie switch 94 and opening the sectionalizing branch 60 and 61.

Table IV. Voltage difference across all open tie switches after fourth switching

S. No	Tie switch Number	Voltage difference across tie switch (pu)
4	94	0.7781

As can be seen from Table V, the real power loss after reconfiguration is 0.11234 MW. and reactive power loss after reconfiguration is 0.116 MVAR as shown in Table VI.

Table V. Optimal real power loss in each loop, minimum node voltages of the switches, switches open

Tie switch (Closed)	Minimum node voltage of tie switch	Sectionalize switch open between nodes	Real Power loss(MW) (After each tie switch is closed)
92	71	**71-72**	**0.14273**
		72-73	0.14334
91	22	**22-23**	**0.12352**
		22-21	0.12356
93	43	**43-44**	**0.13346**
		42-43	0.13536
94	60	**60-61**	**0.11234**
		61-62	0.11245

Table VI. Optimal reactive power loss in each loop, minimum node voltages of the switches, switches open

Tie switch (Closed)	Minimum node voltage of tie switch	Sectionalize switch open between nodes	Reactive Power loss (MVAR)(After each tie switch is closed)
92	71	**71-72**	**0.155**
91	22	**22-23**	**0.131**
93	43	**43-44**	**0.14**
94	60	**60-61**	**0.116**

The optimal radial configuration of the network after all the switching operations is shown in figure 5. Table VII shows the simulation results of the base configuration and the final configuration. The minimum and maximum voltages of the two configurations are depicted in figure 5. The power loss before reconfiguration is 0.27714 MW and reconfiguration is 0.11234 MW. From the results it is observed that percentage reduction in power loss is 59%.

The voltage profiles before and after reconfiguration state is shown in figure 6. It is observed that the minimum voltage before reconfiguration is 0.931 p.u and after reconfiguration is 0.985 pu.

Table VII. Simulation results

	90-bus system
Loss in the base configuration	0.27714 MW, 0.31 MVAR
Loss in the optimal configuration	0.11234MW , 0.116MVAR
Optimal configuration	71,22,43,60
Loss reduction	0.1648 MW, 0.194 MVAR
Loss reduction [%]	59 %

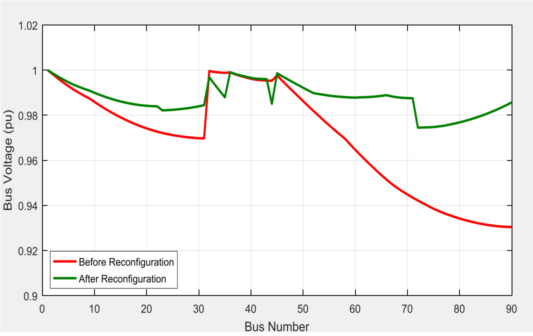

Fig.5. 90- Bus system voltage profile

7. CONCLUTIONS

This paper presents reconfiguration of distribution network under 20MVA, 66/11 kV. Heuristics technique is introduced in this paper. This paper demonstrates the Heuristics technique by using MATLAB software. In the power distribution system, network reconfiguration method improves voltage profile and reduces losses. From the test result of this network, it was observed that the proposed solution was the best optimal configuration. The total real and reactive power are reduced from 0.27714 MW and 0.31MVAR before network reconfiguration state to after network reconfiguration state. So, distribution system losses are reduced about 59%.

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Appendix Network Data for 90- Bus System

Line No	From Bus	To Bus	R(pu)	X(pu)	P(MW)	Q(MVAR)
1	1	2	0.00519	0.00704	0.104	0.078
2	2	3	0.00519	0.00704	0.26	0.195
3	3	4	0.00519	0.00704	0.1638	0.12285
4	4	5	0.00519	0.00704	0.26	0.195
5	5	6	0.00519	0.00704	0.26	0.195
6	6	7	0.00519	0.00704	0.052	0.039
7	7	8	0.00519	0.00704	0.26	0.195
8	8	9	0.00519	0.00704	0.104	0.078
9	9	10	0.00868	0.00738	0.104	0.078
10	10	11	0.00868	0.00738	0.104	0.078
11	11	12	0.00868	0.00738	0.104	0.078
12	12	13	0.00868	0.00738	0.104	0.078
13	13	14	0.00868	0.00738	0.104	0.078
14	14	15	0.00868	0.00738	0.104	0.078
15	15	16	0.00868	0.00738	0.104	0.078
16	16	17	0.00868	0.00738	0.104	0.078
17	17	18	0.00868	0.00738	0.104	0.078
18	18	19	0.00868	0.00738	0.104	0.078
19	19	20	0.00868	0.00738	0.104	0.078
20	20	21	0.00868	0.00738	0.104	0.078
21	21	22	0.00868	0.00738	0.104	0.078
22	22	23	0.00868	0.00738	0.104	0.078
23	23	24	0.00868	0.00738	0.104	0.078
24	24	25	0.00868	0.00738	0.0832	0.0624
25	25	26	0.00868	0.00738	0.052	0.039
26	26	27	0.00868	0.00738	0.052	0.039
27	27	28	0.00868	0.00738	0.104	0.078
28	28	29	0.00868	0.00738	0.0832	0.0624

29	29	30	0.00868	0.00738	0.104	0.078
30	30	31	0.00868	0.00738	0.104	0.078
31	1	32	0.01122	0.00954	0.052	0.039
32	32	33	0.01122	0.00954	0.1638	0.12285
33	33	34	0.01122	0.00954	0.104	0.078
34	34	35	0.01122	0.00954	0.1638	0.12285
35	1	36	0.00922	0.00784	0.1638	0.12285
36	36	37	0.00922	0.00784	0.26	0.195
37	37	38	0.00922	0.00784	0.0832	0.0624
38	38	39	0.00922	0.00784	0.026	0.0195
39	39	40	0.00922	0.00784	0.26	0.195
40	40	41	0.00922	0.00784	0.26	0.195
41	41	42	0.00922	0.00784	0.104	0.078
42	42	43	0.00922	0.00784	0.0832	0.0624
43	43	44	0.00922	0.00784	0.104	0.078
44	1	45	0.00442	0.006	0.1638	0.12285
45	45	46	0.00442	0.006	0.104	0.078
46	46	47	0.00442	0.006	0.052	0.039
47	47	48	0.00442	0.006	0.026	0.0195
48	48	49	0.00442	0.006	0.026	0.0195
49	49	50	0.00442	0.006	0.052	0.039
50	50	51	0.00442	0.006	0.13	0.0975
51	51	52	0.00442	0.006	0.052	0.039
52	52	53	0.00442	0.006	0.052	0.039
53	53	54	0.00442	0.006	0.026	0.0195
54	54	55	0.00442	0.006	0.1638	0.12285
55	55	56	0.00442	0.006	0.1638	0.12285
56	56	57	0.00442	0.006	0.0832	0.0624
57	57	58	0.00442	0.006	0.104	0.078
58	58	59	0.00745	0.00634	0.1638	0.12285
59	59	60	0.00745	0.00634	0.104	0.078
60	60	61	0.00745	0.00634	0.104	0.078
61	61	62	0.00745	0.00634	0.104	0.078
62	62	63	0.00745	0.00634	0.104	0.078
63	63	64	0.00745	0.00634	0.104	0.078
64	64	65	0.00745	0.00634	0.104	0.078
65	65	66	0.00745	0.00634	0.26	0.195
66	66	67	0.00745	0.00634	0.26	0.195
67	67	68	0.00745	0.00634	0.26	0.195
68	68	69	0.00745	0.00634	0.1638	0.12285
69	69	70	0.00745	0.00634	0.104	0.078
70	70	71	0.00745	0.00634	0.104	0.078
71	71	72	0.00745	0.00634	0.104	0.078
72	72	73	0.00745	0.00634	0.026	0.0195
73	73	74	0.00745	0.00634	0.052	0.039
74	74	75	0.00745	0.00634	0.26	0.195
75	75	76	0.00745	0.00634	0.052	0.039
76	76	77	0.00745	0.00634	0.26	0.195
77	77	78	0.00745	0.00634	0.026	0.0195
78	78	79	0.00745	0.00634	0.0832	0.0624
79	79	80	0.00745	0.00634	0.104	0.078
80	80	81	0.00745	0.00634	0.104	0.078
81	81	82	0.00745	0.00634	0.0832	0.0624
82	82	83	0.00745	0.00634	0.104	0.078
83	83	84	0.00745	0.00634	0.104	0.078
84	84	85	0.00745	0.00634	0.104	0.078
85	85	86	0.00745	0.00634	0.052	0.039
86	86	87	0.00745	0.00634	0.1638	0.12285
87	87	88	0.00745	0.00634	0.104	0.078
88	88	89	0.00745	0.00634	0.104	0.078
89	89	90	0.00745	0.00634	0.104	0.078