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RESEARCH ARTICLE OPEN ACCESS

Analysis of Loss Reduction for Radial Distribution System Using Network Reconfiguration

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Abstract:

Nowadays, the electricity demand is increasing daily and hence it is important not only to extract electrical energy from all possible new power resources but also to reduce power losses to an acceptable minimum level in the existing distribution networks where a huge amount of power dissipation occurred. A lot of power is remarkably dissipated in Yangon distribution system. Network reconfiguration method is employed for loss reduction and exhaustive search technique is also applied to achieve the minimal loss switching scheme. Network reconfiguration is performed by opening sectionalizing switches and closing tie switches of the network for loss reduction. The distribution network for existing and reconfiguration conditions are modelled and simulated by Electrical Transient Analyzer Program (ETAP) 7.5 version software. The proposed method is tested on 83-Bus and 74-Bus radial distribution system in Yangon city since it is long-length, overloaded lines and high level of power dissipation is occurred in this system. According to simulation results of load flow analysis, voltage profile enhancement, power loss reduction and cost saving for proposed system are revealed in this paper.

Keywords — exhaustive search technique, loss reduction, load flow analysis, cost saving

I. INTRODUCTION

As the increase in power demand and high load density in the urban areas, the losses in power distribution sector are much occurred. Thus, the power distribution topology is required to change for the better planning of primary distribution system and by increasing the substation capacity and the number of feeders according to obtain the minimal loss configuration. A significant portion of the power that a utility generates is lost in the distribution process. These losses occur in numerous small components in the distribution system, such as transformers and distribution lines. One of the major sources of losses in the distribution system is the power lines which connect the substation to the loads. Network reconfiguration, capacitor placement and distributed generation are among different ways of decreasing losses. As a consequence, the system voltage is also improved. Thus, these two facts are interconnected [1]. As distribution system of case study is radial distribution system, distribution feeder configuration is the best method. Distribution feeder reconfiguration is performed for load balancing and loss reduction during the load transfer from heavy loaded feeder to light loaded feeder. There are two types of switches: normally open switches as tie switch and normally close switches as sectionalizing switch. By closing tie switches in radial distribution system, this network transforms into fully meshed distribution system. In this condition, system power losses are decreased. This is the least power losses the system can have. And the function of sectionalizing switches is to open line between buses in a loop to restore radial distribution system finally. It is noted that if there are five loops in the system, this system should have five sectionalizing switches to be radial distribution network finally [2].

II. 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. Two radial distribution systems in Yangon city which are chosen as case study areas have 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 allow 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 IEC standard at 50 Hz in ETAP [5]. The load flow solutions for three methods in exhaustive search techniques 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

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

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

Bus Voltage Constraint: $V_{min} \leq V \leq V_{max}$ [3]

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

$$P_{Peak\ Loss} = \sum_{mn=1}^{k} \left|I_{mn}\right|^2 \times R_{mn} \quad (3)$$

$$Q_{Peak\ Loss} = \sum_{mn=1}^{k} \left|I_{mn}\right|^2 \times X_{mn} \quad (4)$$

where,

Imn = Current through in the branch (m, n)

Rmn = Resistance in the branch (m, n)

Xmn = Reactance in the branch (m, n) [1]

III. OVERVIEW OF 83-BUS AND 74-BUS DISTRIBUTION NETWORK

Yangon city is the largest load centre in Myanmar. The systems under study are two of the 11kV distribution networks under Yangon Electricity Supply Board (YESB). Power transformer ratings and the values of power factor are 10 MVA and 0.85 and incoming line is 33 kV and conductor size is 120 mm^2. 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 an overhead AC radial distribution system. The single line diagrams of 83-Bus and 74-Bus are shown in Fig. 1 and Fig. 2. The power consumptions of connected loads are not full load condition [4].

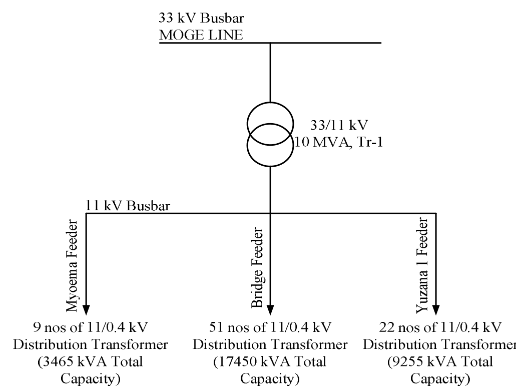

Fig. 1. Single line diagram of 83-bus system

There are three outgoing lines and eighty-two numbers of distribution transformers to supply electricity to consumers and the value of power factor for distribution transformer is 0.83. Although installed capacities for Myoema, Bridge and Yuzana 1 are 3465 kVA, 17450 kVA and 9255 kVA, connected loads for each feeder are 1235 kVA, 3210 kVA and 3914 kVA because some distribution transformers are not full load condition. So, the total power consumption of connected loads for three feeders is 6.9 MW. Load of this system receives a voltage of 400V and lump load [4].

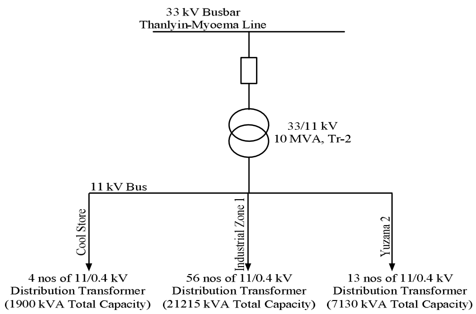

Fig. 2. Single line diagram of 74-bus system

There are three outgoing lines and seventy-three numbers of distribution transformers to supply electricity to consumers and the value of power factor for distribution transformer is 0.83. Although installed capacities for Cool store, Industrial zone 1 and Yuzana 2 are 1900 kVA, 21215 kVA and 7130 kVA, connected loads for each feeder are 600 kVA, 4045 kVA and 3646 kVA because some distribution transformers are not full load condition. So, the total power consumption of connected loads for three feeders is 6.8 MW. Load of this system receives a voltage of 400V and lump load [4].

IV. NETWORK RECONFIGURATION FOR LOSS REDUCTION

Network reconfiguration means restructuring the power lines which connect various buses in a power system. Restructuring of specific lines leads to alternate system configurations. It can be accomplished by placing line interconnection switches into network. Opening and closing a switch connects or disconnect a line to the existing network. Network reconfiguration in distribution systems is performed by opening sectionalizing (normally closed) and closing tie (normally open) switches of the network. These switching are performed in such a way that the radiality of the network is maintained and all the loads are energized. A normally open tie switch is closed to transfer a load from one feeder to another while an appropriate sectionalizing switch is opened to restore the radial structure.

During applying reconfiguration technique, the tie switch has to be closed and on the other hand, the sectionalizing switch has to be opened in the loop created, which restores radial configuration. The switch pairs are chosen through exhaustive formulas for the change in losses. A radial distribution network can be represented by several loops. This is because, when it is connected, one tie-line can only make one loop, the number of loops is equal to the number of tie lines. The benefits of feeder reconfiguration include: (i) restoring power to any outage partitions of a feeder, (ii) relieving overloads on feeders by shifting the load in real time to adjacent feeders, and (iii) reducing resistive line losses. Optimal reconfiguration involves the selection of the best set of branches to be opened, one each from each loop, for reducing resistive line losses, and reliving overloads on feeders by shifting the load to adjacent feeders. This method is commonly used for radial distribution system [6].

V. EXHAUSTIVE SEARCH TECHNIQUES IN NETWORK RECONFIGURATION

Network reconfiguration is done to minimize losses for the existing and new topology of the feeder system and for the purpose of maintenance in the distribution system. Optimization techniques are needed to search the optimal switching scheme. An exhaustive technique for the reconfiguration of distribution networks is used to reduce their line losses under normal operating conditions. By reducing these losses in the distribution systems, cost saving for these systems can be achieved. This paper focuses on reconfiguration of a radial distribution networks to optimize the power distribution process in the feeders and for voltage profile improvement and presents three different methods for reconfiguration. There are three types of methods in exhaustive search techniques for loss reduction. They are minimum branch current, minimum voltage difference and voltage difference based closing/opening switch. The proposed approach is suitable for both planning and operation studies as it is computationally efficient [7].

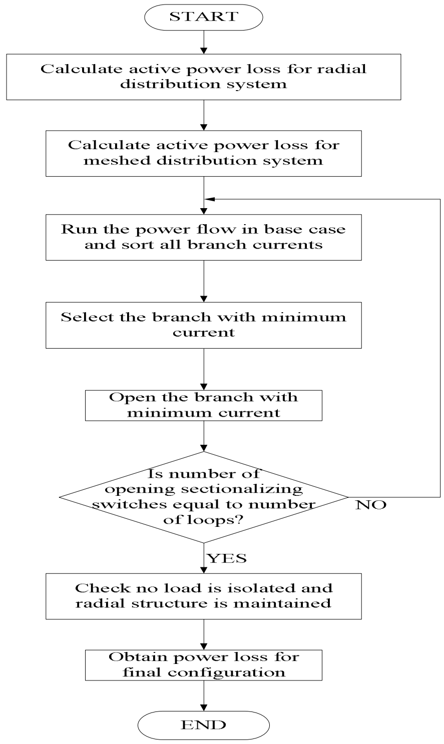

Fig. 3. Flow chart of method 1

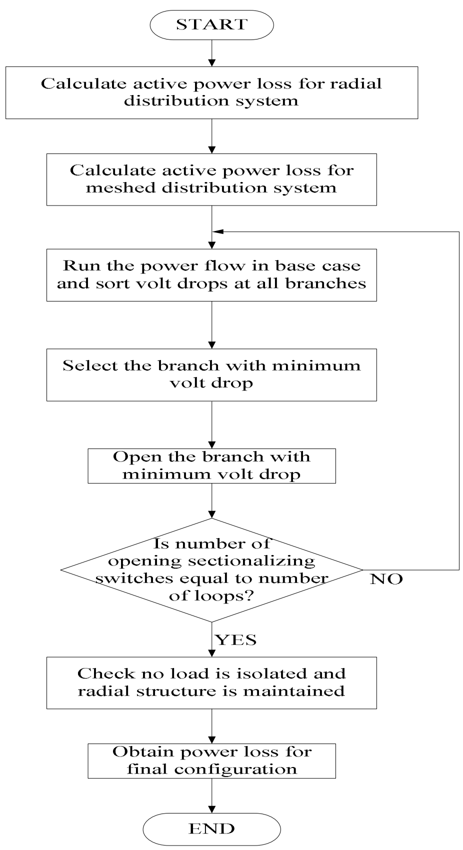

Fig. 4. Flow chart of method 2

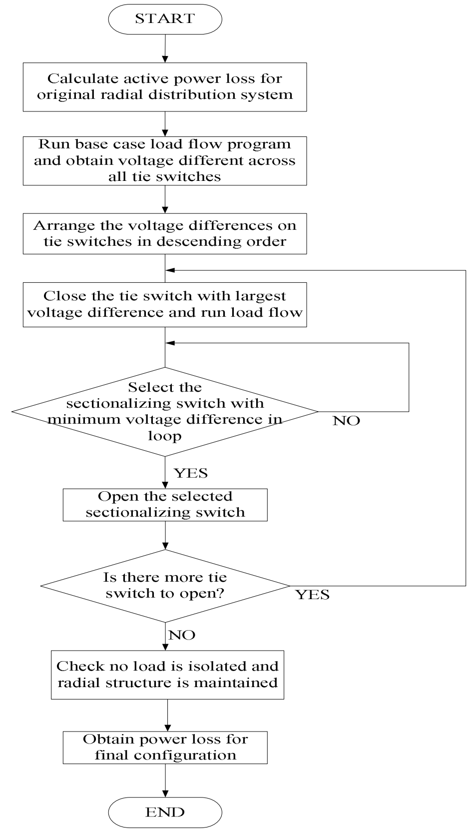

Figure 5. Flow chart of method 3

In this paper, three different methods are proposed with initial configuration and meshed topologies. The initial meshed topology gives the minimum loss configuration for the system and as the network is reconfigured, the radial configuration with minimum losses will occur. The reduction in losses can easily be computed from the results of two load flow studies of the system configuration before and after the feeder reconfiguration. The load flow solutions of both cases are modeled and simulated by using ETAP software. Newton Raphson load flow has been used in the entire reconfiguration process. The flow charts of the three different methods for network reconfiguration are illustrated in Fig. 3, Fig. 4 and Fig. 5.

VI. SIMULATION RESULTS AND DISCUSSION

There are five tie lines before network reconfiguration because of voltage reduction, long length and overloaded lines in the existing radial distribution system. And the minimum operating voltage is nearly 10 kV in the existing system. The distribution systems with tie lines or meshed topology are demonstrated in Fig. 6 and Fig. 7.

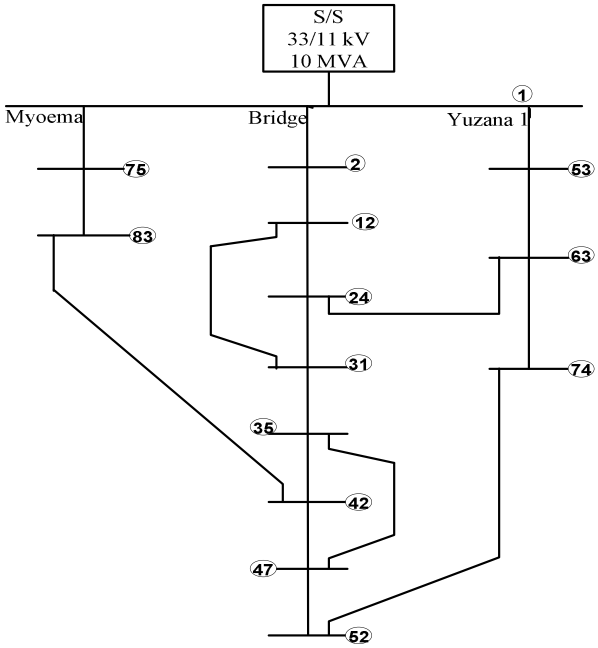

Fig. 6. 83-bus distribution system with tie lines [4]

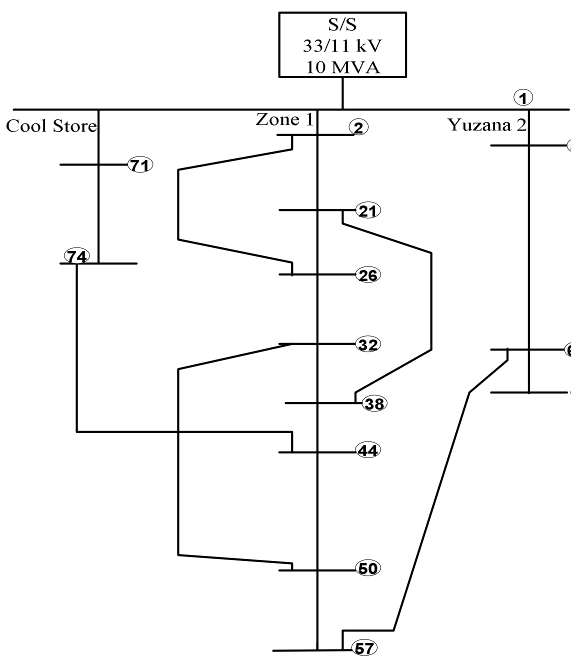

Fig. 7. 74-bus distribution system with tie lines [4]

After using exhaustive search techniques in network reconfiguration process, there are five sectionalizing switches to achieve minimum loss switching configuration. The procedures of network reconfiguration for the two distribution systems are calculated according to the above three flow charts. Among three solutions of three methods in exhaustive search techniques, the best results for test systems are illustrated with the following figures. For 83-bus and 74-bus system, minimum current based reduction method (method 1) is the best method for network reconfiguration process. Final radial distribution systems for the best method in case study are demonstrated in Fig. 8, and Fig. 9.

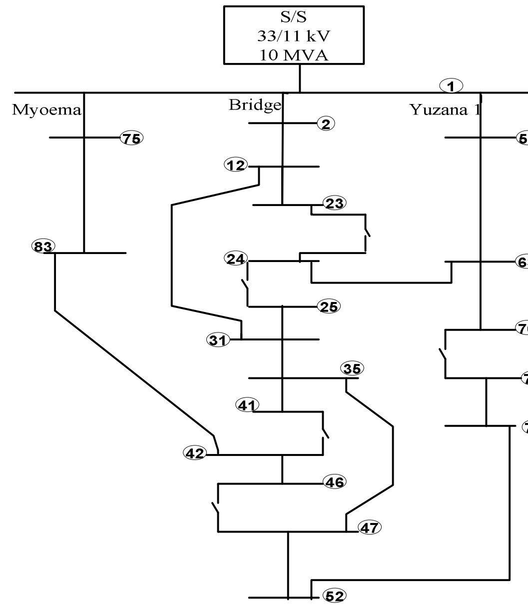

Fig. 8. Final radial distribution systems of 83-bus [4]

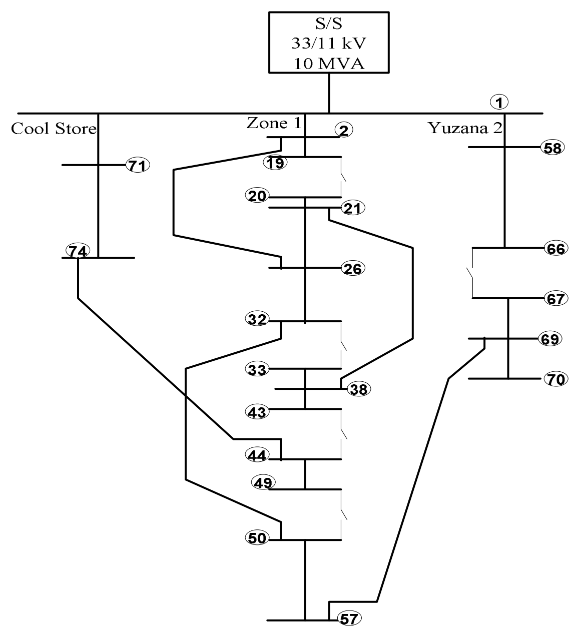

Fig. 9. Final radial distribution systems of 74-bus [4]

Comparison of real and reactive power losses for before and after reconfiguration for three methods in exhaustive techniques of the test systems are depicted in Fig. 10, Fig. 11, Fig. 12, Fig. 13.

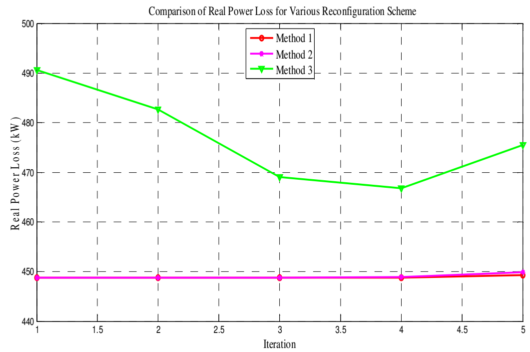

Fig. 10. Comparison of real power loss curves for three methods of 83-bus

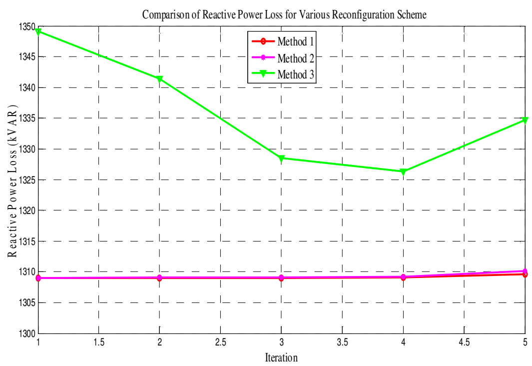

Fig. 11. Comparison of reactive power loss curves for three methods of 83-bus

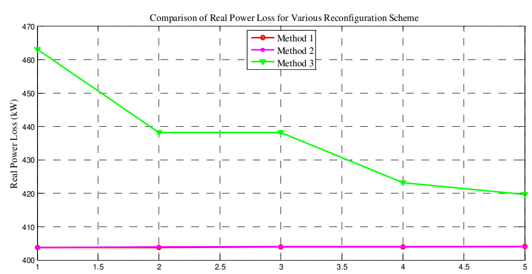

Fig. 12. Comparison of real power loss curves for three methods of 74-bus

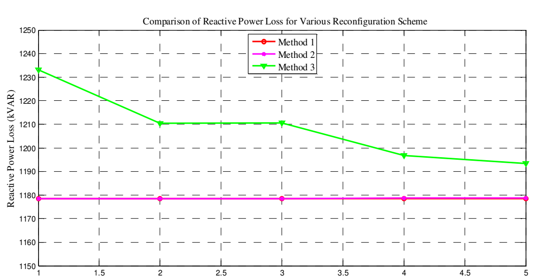

Fig. 13. Comparison of reactive power loss curves for three methods of 74-bus

And then, bus voltage improvement at distribution feeders for before and after reconfiguration of the test system are shown in Figure 14, and Figure 15. The voltage profiles and loss reduction in respective cases are compared subsequently. In the following figures, before reconfiguration condition is expressed in blue colour. Red, pink and green colours are indicated for three methods in exhaustive search technique in reconfiguration process.

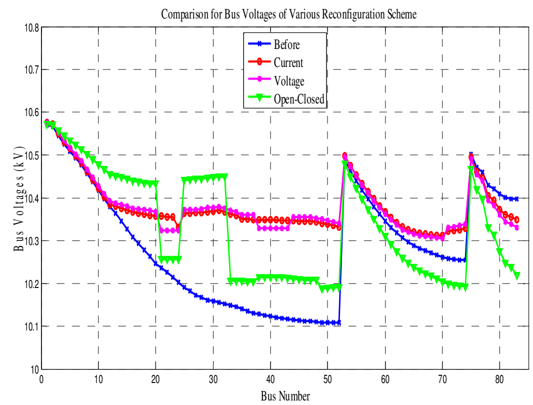

Fig. 14. Comparison of operating bus voltages for before and after reconfiguration of 83-bus

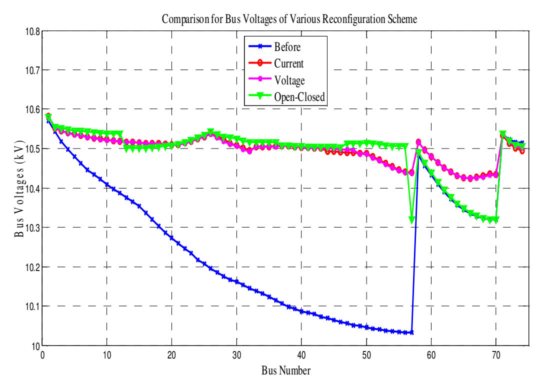

Fig. 15. Comparison of operating bus voltages for before and after reconfiguration of 74-bus

In this condition, all operating bus voltages are dramatically increased above 10.2 kV. By comparing three methods, method 1 or minimum branch current based reduction method is an excellent method because the bus voltages are increased from the lowest voltages, 10.1 kV and 10.03 kV to 10.32 kV and 10.42 kV of the two distribution systems for that condition. Moreover, real and reactive power loss is also reduced. Moreover, equivalent radial distribution diagrams of the optimal method for the two distribution systems after network reconfiguration are shown in Fig. 16 and Fig. 17. The following figures show the equivalent radial distribution system of the best method in network reconfiguration.

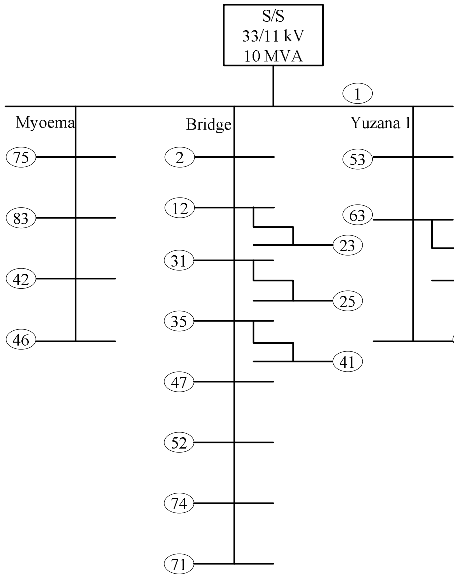

Fig. 16. Equivalent radial distribution system of method 1 for 83-bus system

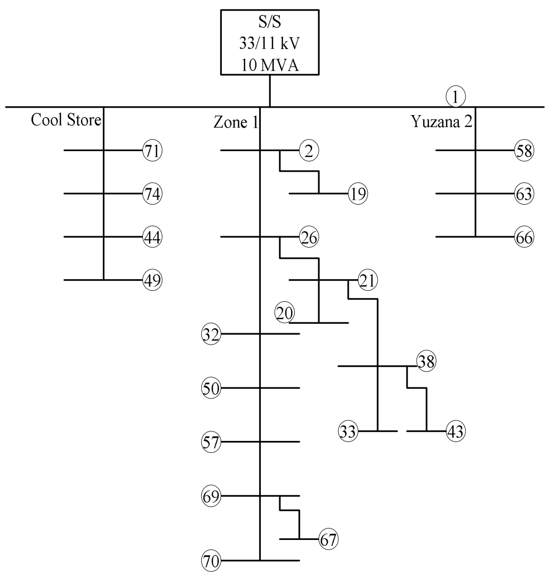

Fig. 17. Equivalent radial distribution system of method 1 for 74-bus system

VII. CONCLUSIONS

Exhaustive technique is used to find the optimal switching configuration and loss minimization to reconfigure this network. ETAP is applied for load flow solutions of three methods to manage the optimal switching scheme with minimum loss. According to the calculation results from the above figures, the power loss for 83-bus and 74-bus are about 491.7kW and 513 kW. With the network reconfiguration scheme, this loss can be reduced from 491.7 kW to 449.3 kW and 513 kW to 404 kW. Therefore 13 million kyats can be saved by network reconfiguration for 83-bus radial distribution system and 33.42 million kyats can be saved for 74-bus radial distribution system. These energy saving is equivalent to saving of about 46.42 millions of kyats in Myanmar economy for two systems in Yangon city. And the minimum operating voltage is 10.108 kV and 10.033 kV in the existing system. After network reconfiguration, all operating bus voltages are dramatically increased to 10.332 kV and 10.439 kV. Though the aim is reducing the real power loss, the reactive power loss is also reducing due to enhancement in voltage profile.

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