Journal of Mining and Earth Sciences

Website: http://tapchi.humg.edu.vn

Modified Algorithm for finding the optimal nod of closed-medium voltage grids

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ARTICLE INFO

Article history:
Received 12 Mar. 2017
Accepted 25 Mar. 2017
Available online 30 June 2017

Keywords:
Medium voltage grid
Open node
Location of open node
Algorithm

ABSTRACT

In MV grid planning, apart from forecasting the power demand, the structure of grid is the key factor that must be taken into account. In Vietnam, MV grids are usually close-structured with one open node. To apply the mode, the location of open node must be specified appropriately. This location will affect not only the technical parameters but also economical ones of grid. The paper presents modified algorithm used to determine the optimal open nod in 22kV grids of Vietnam. Base on the algorithm, some computations are implemented with Dien Bien 22kV grids to prove the effectiveness of nod's location. The results as well as the method presented in the paper will be utilized for further medium voltage grid planning in order to minimize the power losses.

1. Introduction

1.1. Introduction about MV closed-ring distribution grid with normally open node

In the process of power planning, closed-ring grid is preferred rather than tree-lined grid. MV distribution ring grids are usually fitted with a normally-open point or node as shown in Figure 1 (Robert, 2015). To ensure the appropriate selection for relay protection systems and reduce the impact of faults, the normally open node (NON) must be located correctly. In normal operation mode of grid, closed-ring grid is split into two separate routines if the NON is opened. In abnormal operation mode, NON is closed to power the grid from only one side that is not faulted.

In designing or planning urban distribution grids, the location of NON plays an important role because it affects both grid's technical parameter and grid's operation mode. The node's location must be determined correctly because improper location can cause grid's uneconomical operations (Veldman et al., 2013). Moreover, because of improper location, the distribution lines will not be operated near the lines' capacity, it causes to the conductor's aging and the increase of grid power losses. Proper selection of the NON's location secures electricity delivery within constraints including: voltage constraint, frequency and short circuit constraints (NTSOE, 2013) and so on.

In real operation of grid, NON can be used to

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change the structure of grid. Figure 2 Illustrates the restructuring of a MV grid by utilizing 3 NON (Wanyu Cao, 2015).

Because of the NON's importance, many technologies are utilized to determined the appropriate location of NON. However, there are insufficient measuring devices on MV grids therefore real-time determination NON's location is impossible (Werner FEILHAUER, 2014). Figure 3 presents a typical MV closed grid with measuring devices that is impossible real-time determined the suitable NON (Xiang, 2015). Therefore in all Vietnamese MV grids, this determination must be implemented by computer programs or by offline algorithms.

1.2. The mathematic equations utilized to determine the location of NON

Power distribution in a MV grid with NON is shown in Figure 4. To determine exactly the location of NON, the value of power in two first braches in each routine (P_i+jQ_i and P_j + jQ_j) must be specified. The simplified diagram of one branch is shown in Figure 5.

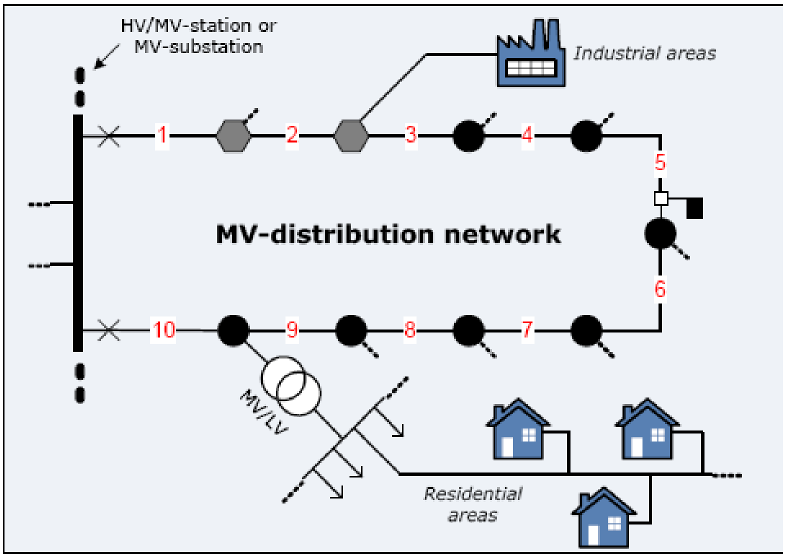

Figure 1. Closed-ring distribution grid with NON (Robert and et al. 2015).

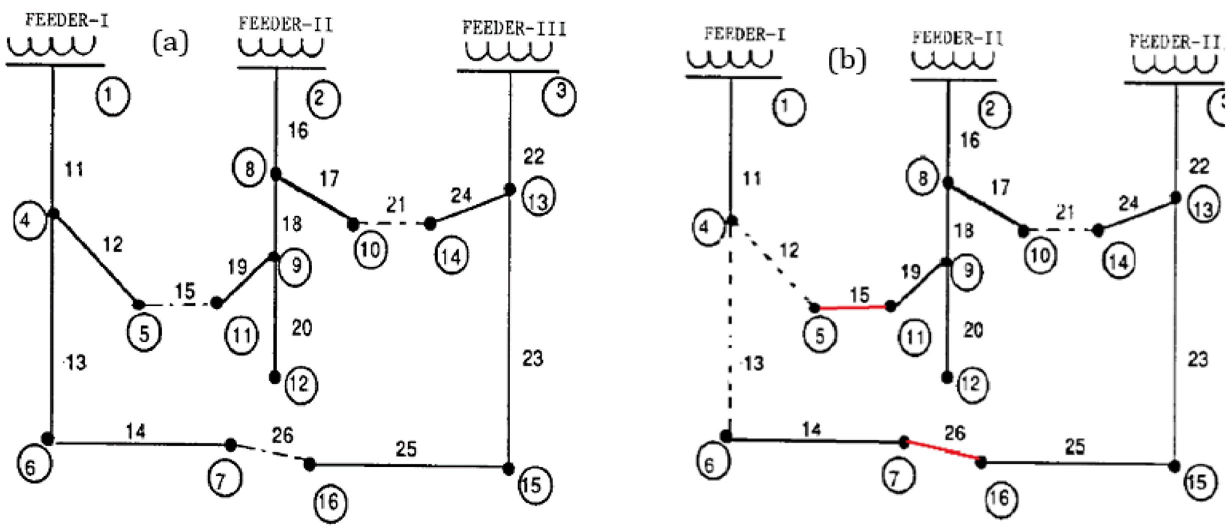

Figure 2. The role of NON in changing the structure of MV grid. (a) Before using NON; (b) After using NON (Wanyu Cao, 2015).

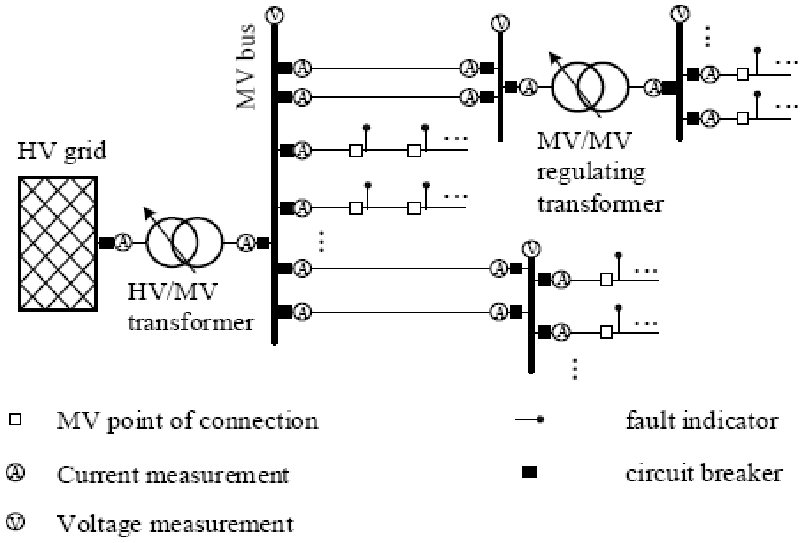

Figure 3. Typical measurement devices in closed MV distribution grid that are not sufficient to locate the NON (Xiang, 2015).

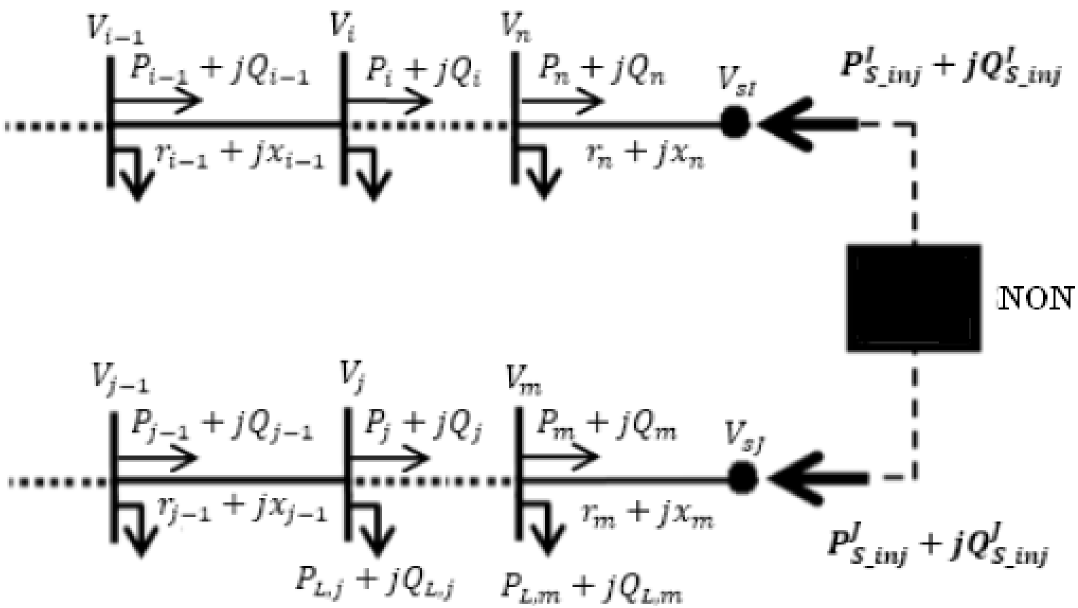

Figure 4. Power distribution in a MV grid with NON.

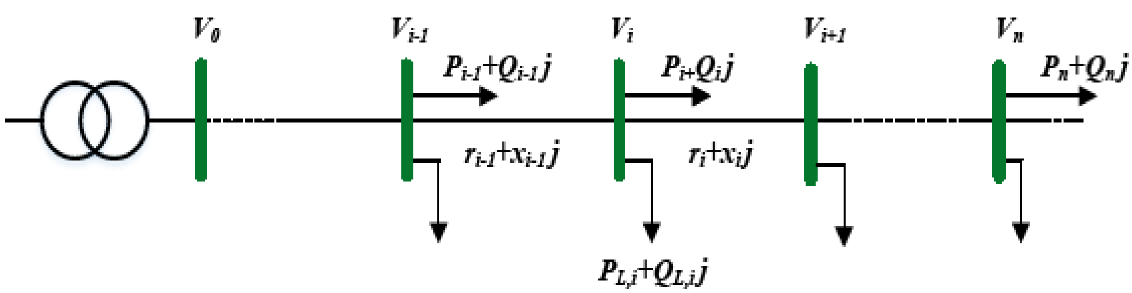

Figure 5. Simplified diagram of one branch MV closed grid.

In normal grid's operation mode, active and reactive power of node *i* is calculated as (1) (Wanyu Cao, 2015)

$$\begin{aligned} P_i &= P_{i-1} - P_{Loss(i=1,i)} - P_{L,i} = \\ &= P_{i-1} - \frac{R_{i-1}}{|V_{i-1}|}.(P_{i-1}^2 + Q_{i-1}^2) - P_{L,i} \\ Q_i &= Q_{i-1} - Q_{Loss(i=1,i)} - Q_{L,i} = \\ &= Q_{i-1} - \frac{X_{i-1}}{|V_{i-1}|}.(P_{i-1}^2 + Q_{i-1}^2) - Q_{L,i} \end{aligned} \quad (1)$$

Where:

R_i, X_i – Resistance and Reactance of line branch i;

V_i – magnitude of voltage i, this value is calculated by (2):

$$\begin{aligned} |V_i|^2 = |V_{i-1}|^2 &- 2(R_{i-1}P_{i-1} + X_{i-1}Q_{i-1}) + \\ &+ \frac{R_{i-1}^2 + X_{i-1}^2}{|V_{i-1}|^2}(P_{i-1}^2 + Q_{i-1}^2) \end{aligned} \quad (2)$$

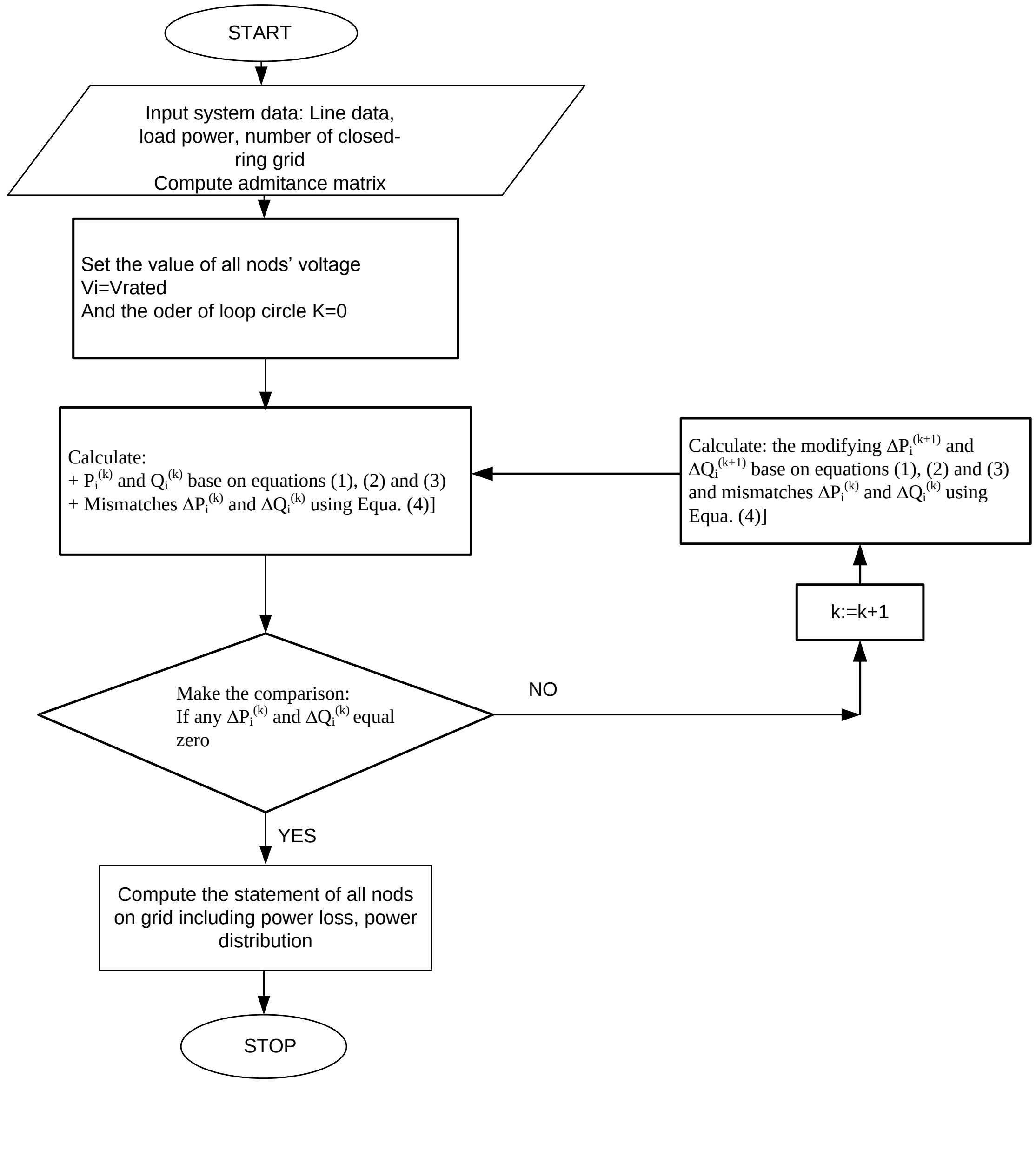

Figure 6: Modified block diagram describing the determining process of NON location.

In small MV grids with rated voltage up to 35kV, the power loss at prior branch can be omitted when calculate the power in the follower branch, therefore powers at node i could be easily computed by (3). In computational calculating, in first stage, these values could be estimated by equation (4) (Xiang Y, 2015).

$$P_i = P_n + \sum_{k=i+1}^{n} P_{L,k} \qquad Q_i = Q_n + \sum_{k=i+1}^{n} Q_{L,k} \tag{3}$$

$$\Delta P_i = P_i^{new} - P_i^{old} = \Delta P_{S\_inj} \qquad \Delta Q_i = Q_i^{new} - Q_i^{old} = \Delta Q_{S\_inj} \tag{4}$$

The above equations will be used to form up the computing diagram for determining the location of NON.

2. Modified algorithm used to locate the position of NON in closed-ring MV grid

2.1. Block diagram describing the determining process of NON location

Base on equations (1), (2), (3) and (4), the following diagram is utilized to determine the location of NON on a closed-ring grid, the usage of the diagram is illustrated in 2.2. The location of NON will be determined whenever the $\Delta P_{S\_inj} = 0$ or $\Delta Q_{S\_inj} = 0$. It means that the power that the source injected to the line is equal zero, the delivery power will be totally equal by load power $P_{L,i} + jQ_{L,i}$.

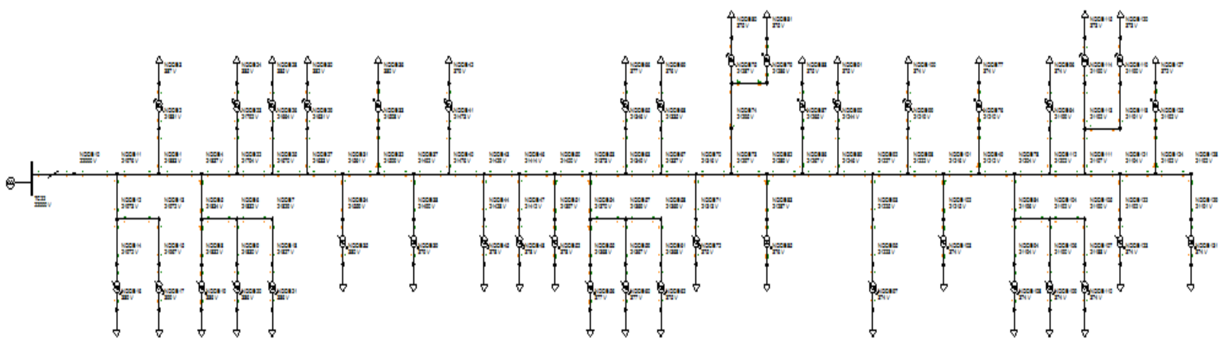

Figure 7. Single line diagram of transmission line No 471 (Dien Bien 22kV MV gird).

Table 1. Nodes data of transmission line number 471.

Name	1st Node	2nd Node	Phase	Library Ref	Maximum Current	Minimum Voltage	Total Branch Power	
							P	Q
Switch1	NODE1	NODE2	ABC	SWITCH22	114	22.000	3.407.504	2.685.116
Line1	NODE2	NODE3	ABC	XLPE185	114	21.994	3.407.504	2.685.116
Line2	NODE3	NODE4	ABC	AC120ND	114	21.961	3.406.781	2.683.973
Line3	NODE4	NODE6	ABC	AC50ND	9	21.959	258.884	203.336
Tran1	NODE6	NODE7	ABC	TRANS400	476	388	258.854	203.319
Line4	NODE4	NODE8	ABC	AC120ND	105	21.931	3.143.698	2.475.629
Line6	NODE8	NODE11	ABC	AC120ND	100	21.896	2.977.963	2.344.628
Line7	NODE11	NODE12	ABC	AC50ND	9	21.894	258.886	203.399
Tran3	NODE12	NODE13	ABC	TRANS400	478	387	258.871	203.390
Line8	NODE11	NODE14	ABC	AC120ND	91	21.857	2.715.044	2.136.420
Line9	NODE14	NODE15	ABC	AC50ND	9	21.854	258.913	203.452
Tran4	NODE15	NODE16	ABC	TRANS400	478	386	258.882	203.435
Line10	NODE14	NODE17	ABC	AC120ND	82	21.827	2.452.098	1.928.159
Line11	NODE17	NODE18	ABC	AC50ND	9	21.825	258.921	203.484
Tran5	NODE18	NODE19	ABC	TRANS400	479	386	258.891	203.468

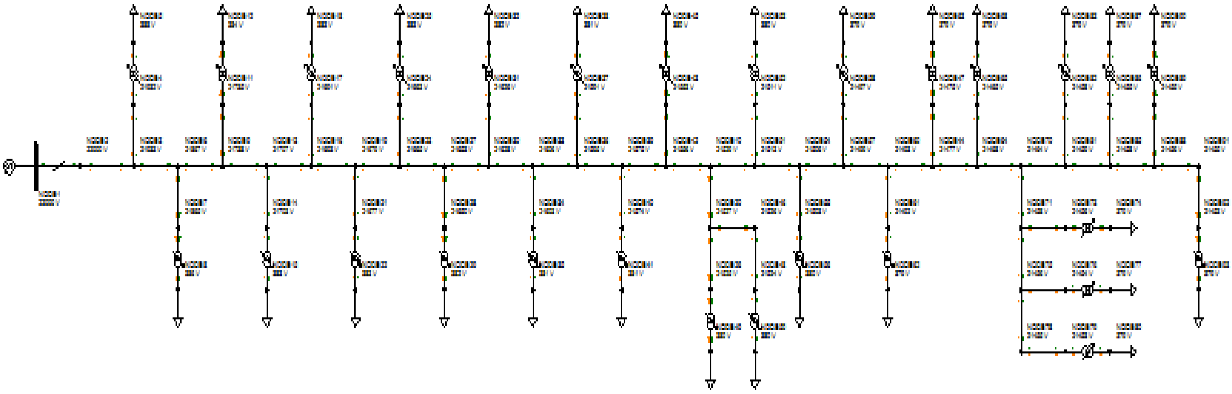

Figure 8. Single line diagram of transmission line No 471 (Dien Bien 22kV MV gird).

Figure 9. Single line diagram of transmission line No 471 and 474 after being restructured (Dien Bien 22kV MV gird).

Table 2. Comparison results of 2 method determination the location of NON, before and after apply the modified algorithm.

Line 471-474	Line 472-475
Iteration 1 Switch Switch34 [NODE164-NODE167] closed. Switch Switch63 [NODE1-NODE175] opened. New system loss: 527.41 kW 1012.04 kVar Iteration 2 Switch Switch63 [NODE1-NODE175] closed. Switch Switch63 [NODE1-NODE175] opened. New system loss: 527.41 kW 1012.04 kVar Initial system loss:532.12 kW 1016.94 kVar Final system loss: 527.41 kW 1012.04 kVar	Iteration 1 Switch Switch55 [NODE297-NODE299] closed. Switch Switch56 [NODE1-NODE164] opened. New system loss: 543.52 kW 1035.90 kVar Iteration 2 Switch Switch56 [NODE1-NODE164] closed. Switch Switch56 [NODE1-NODE164] opened. New system loss: 543.52 kW 1035.90 kVar Initial system loss: 548.69 kW 1041.32 kVar Final system loss: 543.52 kW 1035.90 kVar

2.2. Applied results

Utilizing the above block diagram and the computing procedure in built in software combine with the calculation in PSSY for 22kV MV grid of Dien Bien province, the following results are deducted:

+ The diagram of line number 471 and 474 of 22kV Dien Bien MV Grid is shown in figure 7 and 8. Some data of nodes in these lines are presented in table 1. The lines are operated in single routine mod, the calculation (before and after restructuring) are shown in Table 2 (Dinh Vuong Duy, 2016). After planning, the lines 471 and 474 are restructured. They are combined to operate with a NON.

The modified algorithm applied to determine the new NON resulted a lower power losses on grid. Results of line 472 and 475 which are implemented similarly are shown in Table 2.

The above results show the effectiveness of the proposed algorithm, the suitable NON location is selected with technical satisfaction. It also brings economical effort because the power losses is reduced. The final system loss is reduced significantly than the one of prior NON location. Furthermore, because nodes' voltage are considered as rated voltage, the calculating intergration is very limited (only 2 interation as shown in Table 2).

3. Conclusion

The paper presented a new algorithm to find the optimal location of NON in closed-ring MV grid. The application of algorithm brings the following advantages:

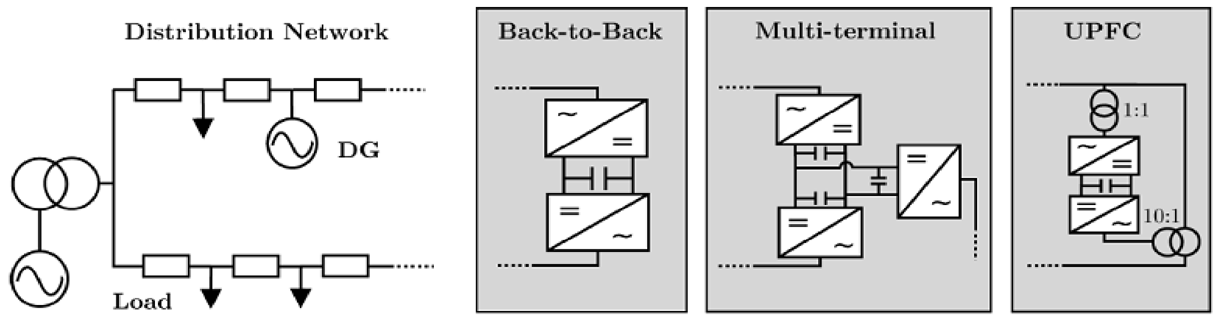

Figure 10. Recommended grid with Soft Open Point.

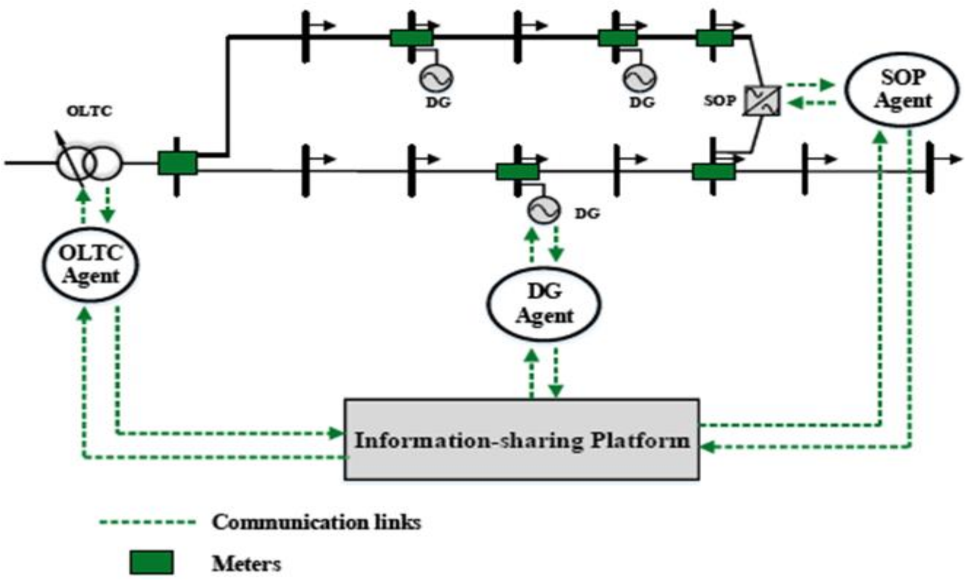

Figure 11. MV grid with online feed back controller to supply power smoothly in abnormal conditions (Fabio Bignucolo et al).

+ Applicable for any close-ring MV grid to determine the location of NON;

+ The new selection result can cause a smaller power loss on MV grid.

+ Usable to estimate the restructuring ability of 2 single routine lines in order to form a closed-ring grid.

+ With the assumption that voltage of all nodes on grid are rated one, the algorithm can fulfill the calculation in limited integrations.

4. Future Scope

The determination of NON location mentioned above is only suitable for grids' normal operating conditions. In abnormal operations, the grid will be separated into 2 single routines that operate in forced hard conditions with poor state parameters. Therefore, in future of Vietnamese MV grid, a structure of grid with Soft Open Point is recommended.

This kind of node can flexible adapt to the normal as well as abnormal condition of grid. The suggestion model of grid is shown in Figure 10. The power flows in this type of grid can be smoothly controlled by applying the modern of online feed back controller that can be seen in Figure 11.

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