Network Reduction For Distribution Systems

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The buses in distribution systems are interconnected by switchable and non-switchable lines. If we are only concerned with switches, the size of the network can be reduced such that only switchable lines are present. The idea is to combine all the buses between switchable lines to form a "bus block".

Consider the 18-bus distribution network shown in Fig. 1. Let Ω_K be the set of lines and Ω_{SW} the set of lines with switches. We first remove all switchable lines and create the subset $\bar{\Omega}_K = \Omega_K/\Omega_{SW}$, which contains non-switchable lines only. Subsequently, Fig. 1 is converted to the network shown in Fig. 2. Fig. 2 shows that there are 6 bus blocks in this network. The goal is to combine the buses in each bus block to reduce the size of the network. For example, buses $\{2, 9, 10\}$ becomes bus **2**, and buses $\{4, 5\}$ become bus **3**. Once all bus blocks are identified, the switchable lines are reinstated, as shown in Fig. 3.

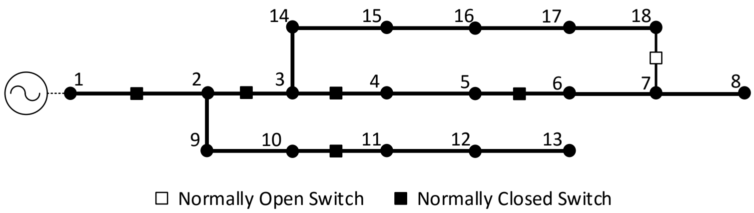

Figure 1: 18-bus distribution network with 6 controllable switches

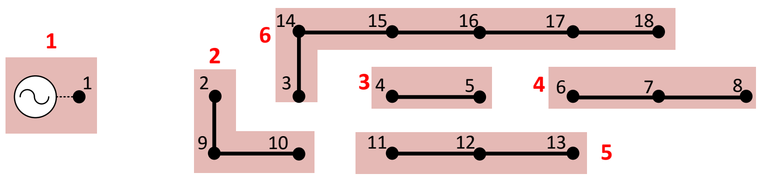

Figure 2: 18-bus distribution network with 6 controllable switches removed

The distribution network can be represented by a graph G containing nodes (buses) and edges (distribution lines). Each line k in the distribution network consists of two connected

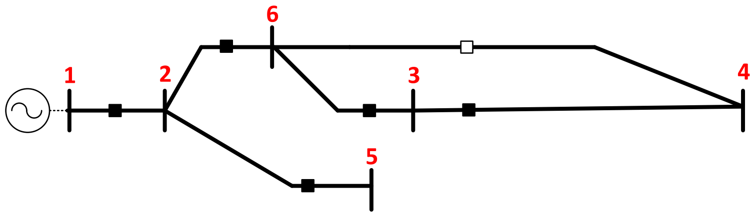

Figure 3: The 18-bus distribution network reduced to 6 buses

buses: $k(1)$ and $k(2)$. For example, line k = 4–5 has the parameters $k(1) = 4$ and $k(2) = 5$.

The network reduction algorithm is shown in Algorithm 1. The first step of the algorithm is to remove all switchable lines from the distribution network. After removing the lines, we define the new distribution network in step 2, where the nodes are in the set Ω_B and the edges are in the set $\bar{\Omega}_K$. To combine the buses and form the bus blocks, we must identify the bus block that each bus is associated with. Each bus i is clustered to a bus block $B(i)$, which is initialized in step 3. Step 4 initializes the bus block number b. For each line k with buses $n = k(1)$ and $k(2)$, we identify the buses connected to n and label the buses by the bus block number b. The bus block number for each bus $k(n)$ is stored in $B(k(n))$. If the bus is already labelled, then the loop is skipped in step 7. The bus block number and $B(k(n))$ are updated in steps 8 and 9, respectively. In step 10, a depth first search method is used to find all the buses connected to bus $k(n)$. In step 11, we assign a bus block number b to the buses in N. The data for the lines in the reduced network is stored in $Bus\_A(k)$ and $Bus\_B(k)$. Therefore, the reduced network will contain the bus blocks $\{1...b\}$, switchable lines, and the pair of buses ($Bus\_A(k)$,$Bus\_B(k)$) connecting each line.

Algorithm 1 Network Reduction Algorithm

1: Define non-switchable lines $\bar{\Omega}_K = \Omega_K / (\Omega_{SW} \cup \Omega_{FS})$
2: Define graph $G(\Omega_B, \bar{\Omega}_K)$
3: Let $B(i) = 0, \forall i \in \Omega_B$
4: Initialize $b = 0$
5: **for** $k \in (\Omega_{SW} \cup \Omega_{FS})$ **do**
6:     **for** $n = 1$ to 2 **do**
7:         **if** $B(k(n)) == b$ **then**
8:             $b = b + 1$
9:             $B(k(n)) = b$
10:             $N = Depth\ First\ Search(G(\Omega_B, \bar{\Omega}_K), k(n))$
11:             $B(i) = b, \forall i \in N$
12:         **end if**
13:     **end for**
14:     $[Bus\_A(k), Bus\_B(k)] = [B(k(1)), B(k(2))]$
15: **end for**