## APPENDIX A

### THE KKT TRANSFORMATION WITH LINEARIZATION PROCESS

The lagrangian function for the original lower-level problem (32)-(37) is:

$$
\begin{aligned}
L = \sum_{n\in \boldsymbol{V_T}} \Delta Pd_n - \sum_{l\in \boldsymbol{L}} \mu_l \left( p_l - v_l \cdot \frac{1}{x_l} \cdot \sum_{n\in \boldsymbol{V_T}} A_{nl} \cdot \delta_n \right) \\
- \sum_{n\in \boldsymbol{V_T}} \lambda_n \left( \sum_{g\in \boldsymbol{G_n}} p_g - \sum_{l\in \boldsymbol{L}} A_{nl} \cdot p_l + \Delta Pd_n - Pd_n \right) \\
- \sum_{l\in \boldsymbol{L}} \underline{\omega}_l \left( p_l + \overline{p}_l \right) - \sum_{l\in \boldsymbol{L}} \overline{\omega}_l \left( \overline{p}_l - p_l \right) \\
- \sum_{j\in \boldsymbol{G}} \underline{\theta}_j \left( g_j - \underline{g}_j \right) - \sum_{j\in \boldsymbol{G}} \overline{\theta}_j \left( \overline{g}_j - g_j \right) \\
- \sum_{n\in \boldsymbol{V_T}} \underline{\alpha}_n \left( \Delta pd_n \right) - \sum_{n\in \boldsymbol{V_T}} \overline{\alpha}_n \left( Pd_n - \Delta Pd_n \right)
\end{aligned} \qquad \text{(A1)}
$$

Where $\mu_l$, $\lambda_n$, $\underline{\omega}_l$, $\overline{\omega}_l$, $\underline{\theta}_j$, $\overline{\theta}_j$, $\underline{\alpha}_n$, $\overline{\alpha}_n$ are the Lagrangian multipliers associated with the DC power flow constraints (33)-(37), respectively, in addition to the original feasibility constraints (33)-(37), the optimality conditions for the original problem KKT are:

$$\frac{\partial L}{\partial \delta_n} = \sum_{l\in \boldsymbol{L}} \frac{1}{x_l} A_{nl} \mu_l v_l = 0, \qquad n \in \boldsymbol{V_T} \qquad \text{(A2)}$$

$$\frac{\partial L}{\partial g_j} = -\lambda_n - \underline{\theta}_j + \overline{\theta}_j = 0, \qquad j \in \boldsymbol{G} \qquad \text{(A3)}$$

$$\frac{\partial L}{\partial p_l} = \sum_{n\in \boldsymbol{V_T}} A_{nl} \lambda_n - \mu_l - \underline{\omega}_l + \overline{\omega}_l = 0, \quad l \in \boldsymbol{L} \qquad \text{(A4)}$$

$$\frac{\partial L}{\partial \Delta Pd_n} = 1 - \lambda_n - \underline{\alpha}_n + \overline{\alpha}_n = 0, \qquad n \in \boldsymbol{V_T} \qquad \text{(A5)}$$

$$\underline{\omega}_l \geq 0, \qquad l \in \boldsymbol{L} \qquad \text{(A6)}$$

$$\overline{\omega}_l \geq 0, \qquad l \in \boldsymbol{L} \qquad \text{(A7)}$$

$$\underline{\theta}_j \geq 0, \qquad j \in \boldsymbol{G} \qquad \text{(A8)}$$

$$\overline{\theta}_j \geq 0, \qquad j \in \boldsymbol{G} \qquad \text{(A9)}$$

$$\underline{\alpha}_n \geq 0, \qquad n \in \boldsymbol{V_T} \qquad \text{(A10)}$$

$$\overline{\alpha}_n \geq 0, \qquad n \in \boldsymbol{V_T} \qquad \text{(A11)}$$

$$\underline{\omega}_l \left( p_l + \overline{p}_l \right) = 0, \qquad l \in \boldsymbol{L} \qquad \text{(A12)}$$

$$\overline{\omega}_l \left( \overline{p}_l - p_l \right) = 0, \qquad l \in \boldsymbol{L} \qquad \text{(A13)}$$

$$\underline{\theta}_j \left( g_j - \underline{g}_j \right) = 0, \qquad j \in \boldsymbol{G} \qquad \text{(A14)}$$

$$\overline{\theta}_j \left( \overline{g}_j - g_j \right) = 0, \qquad j \in \boldsymbol{G} \qquad \text{(A15)}$$

$$\underline{\alpha}_n \left( \Delta Pd_n \right) = 0, \qquad n \in \boldsymbol{V_T} \qquad \text{(A16)}$$

$$\overline{\alpha}_n \left( Pd_n - \Delta Pd_n \right) = 0, \qquad n \in \boldsymbol{V_T} \qquad \text{(A17)}$$

where (A2)- (A11) denotes the original lower-level problem dual constraints and (A12)- (A17) denotes the complementary slackness constraints.

It can be seen that the original lower-level problem line flow formulation (33), dual constraints (A2) and complementary slackness constraints (A12)- (A17) are all non-linear terms. The above constraints are linearized by the following method:

(1) For the linearization of formulation ((33)

In formulation (33), there are two non-linear terms-- $v_l$ multiplied by the phase angle $\delta_l^f$ at the beginning of the line and $v_l$ multiplied by the phase angle $\delta_l^t$ at the end of the line, so continuous variables $s_l^f$ and $s_l^t$ are introduced to represent $v_l\delta_l^f$ and $v_l\delta_l^t$ respectively. Further intermediate variables $z_l^f$ and $z_l^t$ are introduced to equate the non-linear term (33) with the following linear terms:

$$p_l = \frac{1}{x_l} \cdot \left( z_l^f - z_l^t \right), \qquad l \in \boldsymbol{L} \qquad \text{(A18)}$$

$$z_l^f = \delta_l^f - s_l^f, \qquad l \in \boldsymbol{L} \qquad \text{(A19)}$$

$$z_l^t = \delta_l^t - s_l^t, \qquad l \in \boldsymbol{L} \qquad \text{(A20)}$$

$$\underline{\delta} \cdot v_l \leq z_l^f \leq \overline{\delta} \cdot v_l, \qquad l \in \boldsymbol{L} \qquad \text{(A21)}$$

$$\underline{\delta} \cdot v_l \leq z_l^t \leq \overline{\delta} \cdot v_l, \qquad l \in \boldsymbol{L} \qquad \text{(A22)}$$

$$\underline{\delta} \cdot \left( 1 - v_l \right) \leq s_l^f \leq \overline{\delta} \cdot \left( 1 - v_l \right), \qquad l \in \boldsymbol{L} \qquad \text{(A23)}$$

$$\underline{\delta} \cdot \left( 1 - v_l \right) \leq s_l^t \leq \overline{\delta} \cdot \left( 1 - v_l \right), \qquad l \in \boldsymbol{L} \qquad \text{(A24)}$$

The formulations(A18)-(A24) represents the linearized expression for the calculation of the line DC power flow, if line $l$ is destroyed ( $v_l = 0$ ), then according to the formulations (A21), (A22) can be obtained: $z_l^f$=0, $z_l^t$=0, so the line power flow $p_l$=0, $s_l^f$=$\delta_l^f$, $s_l^t$=$\delta_l^t$; if $l$ is not destroyed ($v_l$=1), then according to the formulations (A23), (A24) can be obtained: $s_l^f$=0, $s_l^t$=0, so $z_l^f$=$\delta_l^f$, $z_l^t$=$\delta_l^t$, and the line plow flow $p_l$ is determined by the phase angle difference between the two ends of the line.

(2) Linearization for the dual constraint (A2)

Similarly, by introducing the continuous variables $t_l$ and $h_l$, the nonlinear dual constraint (A2) is equivalently represented by the following set of linearization constraints:

$$\sum_{l\in L} \frac{1}{x_l} \cdot A_{nl} \cdot t_l = 0, \qquad n \in \boldsymbol{V_T} \qquad \text{(A25)}$$

$$t_l = u_l - h_l, \qquad l \in \boldsymbol{L} \qquad \text{(A26)}$$

$$\underline{u}_l \cdot v_l \leq t_l \leq v_l \cdot \overline{u}_l, \qquad l \in \boldsymbol{L} \qquad \text{(A27)}$$

$$\underline{u}_l \cdot \left( 1 - v_l \right) \leq h_l \leq \overline{u}_l \cdot \left( 1 - v_l \right), \ l \in \boldsymbol{L} \qquad \text{(A28)}$$

(3) Linearization for the complementary slackness constraints (A12)- (A17)

The nonlinear complementary slackness constraints (A12)-(A17) are equivalently represented by the following set of linearization constraints by introducing the 0-1 variables $\omega_l^{\underline{\omega}}$, $\omega_l^{\overline{\omega}}$, $\omega_g^{\underline{\theta}}$, $\omega_g^{\overline{\theta}}$ , $\omega_n^{\underline{\alpha}}$, $\omega_n^{\overline{\alpha}}$ :

$$\underline{\omega}_l \leq M \cdot \omega_l^{\underline{\omega}}, \qquad l \in \boldsymbol{L} \qquad \text{(A29)}$$

$$p_l + \overline{p}_l \leq M \cdot \left( 1 - \omega_l^{\underline{\omega}} \right), \qquad l \in \boldsymbol{L} \qquad \text{(A30)}$$

$$\overline{\omega}_l \le M \cdot \omega_l^{\bar{\omega}}, \qquad l \in \boldsymbol{L} \qquad \text{(A31)}$$

$$\bar{p}_l - p_l \le M \cdot \left(1-\omega_l^{\bar{\omega}}\right), \qquad l \in \boldsymbol{L} \qquad \text{(A32)}$$

$$\underline{\theta}_j \le M \cdot \omega_j^{\underline{\theta}}, \qquad j \in \boldsymbol{G} \qquad \text{(A33)}$$

$$g_j - \underline{g}_j \le M \cdot \left(1-\omega_j^{\underline{\theta}}\right), \qquad j \in \boldsymbol{G} \qquad \text{(A34)}$$

$$\bar{\theta}_j \le M \cdot \omega_j^{\bar{\theta}}, \qquad j \in \boldsymbol{G} \qquad \text{(A35)}$$

$$\bar{g}_j - g_j \le M \cdot \left(1-\omega_j^{\bar{\theta}}\right), \qquad j \in \boldsymbol{G} \qquad \text{(A36)}$$

$$\underline{\alpha}_n \le M \cdot \omega_n^{\underline{\alpha}}, \qquad n \in \boldsymbol{V_T} \qquad \text{(A37)}$$

$$\Delta p_n^d \le M \cdot \left(1-\omega_n^{\underline{\alpha}}\right), \qquad n \in \boldsymbol{V_T} \qquad \text{(A38)}$$

$$\bar{\alpha}_n \le M \cdot \omega_n^{\bar{\alpha}}, \qquad n \in \boldsymbol{V_T} \qquad \text{(A39)}$$

$$p_n^d - \Delta p_n^d \le M \cdot \left(1-\omega_n^{\bar{\alpha}}\right), \qquad n \in \boldsymbol{V_T} \qquad \text{(A40)}$$

$$\omega_l^{\underline{\omega}} + \omega_l^{\bar{\omega}} \le 1, \qquad l \in \boldsymbol{L} \qquad \text{(A41)}$$

$$\omega_j^{\underline{\theta}} + \omega_j^{\bar{\theta}} \le 1, \qquad j \in \boldsymbol{G} \qquad \text{(A42)}$$

$$\omega_n^{\underline{\alpha}} + \omega_n^{\bar{\alpha}} \le 1, \qquad n \in \boldsymbol{V_T} \qquad \text{(A43)}$$

where (A29)- (A30), (A31)- (A32), (A33)- (A34), (A35)- (A36), (A37)-(A38) and (A39)-(A40) are linearised equivalent representations of the constraints (A12), (A13), (A14), (A15), (A16) and (A17) respectively. The intermediate variables introduced satisfies formulations (A41)-A43).

In summary, the original lower-level problem after transformation by KKT is expressed as formulations (A18)-(A24), formulations (33)- (37), (A25)- (A28), (A3)- (A11) and (A29)-(A43). Therefore, the transformed vulnerability identification problem is as follows:

$$\max_{a} \sum_{T \in \Omega_T} \pi_T \left( \sum_{i \in \boldsymbol{V}} \Delta P d_{i*}^T \right) \qquad \text{(A44)}$$

s.t. (26)-(29), (33)-(37), (A18)-(A43).

## APPENDIX B

### PARAMETERS OF UTN AND ROAD NETWORK

Table VI contains information such as the road lengths, the number of cables on the roads, and $E_{ij}$ for each road in the case of Figure B1.

TABLE VI

ROAD NETWORK CONNECTION RELATION AND PARAMETER

| $l_{ij}$ | $d_{ij}$(km) | $mra_{ij}$ | $mrb_{ij}$ | $mrc_{ij}$ | $E_{ij}$ |
|---|---|---|---|---|---|
| 1-2 | 1.8 | 0 | 0 | 0 | 0 |
| 1-3 | 1.6 | 0 | 0 | 0 | 0 |
| 2-51 | 1.7 | 0 | 0 | 0 | 0 |
| 2-52 | 1.7 | 0 | 0 | 0 | 0 |
| 3-4 | 1.3 | 0 | 0 | 0 | 0 |
| 3-12 | 1.9 | 0 | 0 | 0 | 0 |
| 4-5 | 1.7 | 0 | 0 | 0 | 0 |
| 4-12 | 1.7 | 0 | 0 | 1 | 0.43 |
| 5-6 | 1.8 | 0 | 0 | 0 | 0 |
| 6-9 | 1.5 | 3 | 0 | 0 | 0.93 |
| 6-10 | 1.5 | 2 | 0 | 0 | 0.95 |
| 6-13 | 1.5 | 2 | 0 | 0 | 0.78 |
| 7-8 | 1.3 | 2 | 0 | 0 | 0.87 |
| 7-11 | 1.3 | 4 | 0 | 0 | 0.95 |
| 8-10 | 1.32 | 3 | 0 | 0 | 0.97 |
| 8-30 | 1.2 | 3 | 0 | 0 | 0.92 |
| 9-13 | 1.5 | 3 | 0 | 0 | 0.83 |
| 9-16 | 1.5 | 2 | 0 | 0 | 0.84 |
| 9-49 | 1.6 | 2 | 0 | 0 | 0.86 |
| 10-16 | 1.6 | 3 | 0 | 0 | 0.97 |
| 11-17 | 1.3 | 0 | 0 | 0 | 0 |
| 11-30 | 1.1 | 3 | 0 | 0 | 0.96 |
| 12-13 | 1.3 | 0 | 1 | 0 | 0.6 |
| 12-52 | 1.8 | 0 | 0 | 0 | 0 |
| 13-15 | 1.5 | 2 | 0 | 0 | 0.75 |
| 14-32 | 1 | 0 | 0 | 0 | 0 |
| 14-50 | 1 | 0 | 0 | 0 | 0 |
| 15-49 | 1.3 | 3 | 0 | 0 | 0.97 |
| 15-54 | 1.27 | 3 | 0 | 0 | 0.98 |
| 16-31 | 1.2 | 2 | 0 | 0 | 0.9 |
| 16-50 | 1.12 | 1 | 0 | 0 | 0.97 |
| 17-18 | 0.9 | 4 | 0 | 0 | 0.36 |
| 18-19 | 1 | 0 | 2 | 0 | 0 |
| 18-21 | 1.28 | 3 | 0 | 0 | 0.55 |
| 18-30 | 1.22 | 2 | 0 | 0 | 0 |
| 19-20 | 1.12 | 3 | 0 | 0 | 0 |
| 19-22 | 1.15 | 1 | 0 | 0 | 0.57 |
| 20-23 | 1.3 | 4 | 0 | 0 | 0 |
| 20-24 | 1.35 | 3 | 0 | 0 | 0 |
| 21-22 | 1.4 | 0 | 0 | 1 | 0.63 |
| 21-31 | 1.39 | 0 | 0 | 0 | 0.92 |
| 21-33 | 1.29 | 0 | 2 | 0 | 0.92 |
| 22-29 | 1.23 | 0 | 0 | 0 | 0 |
| 23-25 | 2.1 | 0 | 0 | 0 | 0 |
| 24-25 | 1.4 | 0 | 0 | 2 | 0 |
| 24-26 | 1.6 | 0 | 0 | 0 | 0 |
| 25-27 | 1.5 | 0 | 0 | 0 | 0 |
| 26-27 | 1.57 | 0 | 0 | 2 | 0.76 |
| 26-29 | 1.05 | 4 | 0 | 0 | 0.75 |
| 26-37 | 4 | 3 | 0 | 0 | 0 |
| 27-28 | 1.9 | 0 | 0 | 0 | 0 |
| 28-37 | 3 | 0 | 0 | 0 | 0 |
| 28-38 | 3.5 | 0 | 0 | 0 | 0 |
| 29-35 | 2 | 0 | 0 | 0 | 0.93 |
| 30-31 | 2.3 | 3 | 0 | 0 | 0.95 |
| 31-32 | 1.8 | 3 | 0 | 0 | 0.93 |
| 32-33 | 2 | 5 | 0 | 0 | 0.93 |
| 32-45 | 2.2 | 0 | 0 | 0 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| 33-34 | 1.7 | 3 | 0 | 0 | 0.89 |
| 34-35 | 1.82 | 4 | 0 | 0 | 0.89 |
| 34-44 | 2 | 2 | 0 | 0 | 0.68 |
| 35-36 | 1.5 | 2 | 0 | 0 | 0.89 |
| 36-37 | 1.4 | 3 | 0 | 0 | 0.9 |
| 36-41 | 2.7 | 0 | 0 | 0 | 0 |
| 36-44 | 1.7 | 2 | 0 | 0 | 0.87 |
| 37-40 | 3.7 | 0 | 0 | 0 | 0 |
| 38-39 | 1.9 | 0 | 0 | 0 | 0 |
| 39-40 | 1.7 | 1 | 0 | 0 | 0.56 |
| 39-85 | 2.1 | 0 | 0 | 0 | 0 |
| 40-41 | 1.82 | 1 | 0 | 0 | 0.6 |
| 40-65 | 1.95 | 0 | 0 | 0 | 0 |
| 41-42 | 1.67 | 3 | 0 | 0 | 0.96 |
| 41-43 | 1.32 | 2 | 0 | 0 | 0.87 |
| 42-61 | 1.65 | 4 | 0 | 0 | 0.95 |
| 42-65 | 0.89 | 0 | 0 | 0 | 0 |
| 43-44 | 1.32 | 3 | 0 | 0 | 0.93 |
| 44-46 | | 2 | 0 | 0 | 0.89 |
| 45-46 | 1.4 | 0 | 0 | 0 | 0 |
| 45-47 | 1.6 | 3 | 0 | 0 | 0.79 |
| 46-61 | 1.62 | 4 | 0 | 0 | 0.95 |
| 47-48 | 1.45 | 3 | 0 | 0 | 0.9 |
| 47-50 | 1.7 | 0 | 0 | 0 | 0 |
| 47-60 | 1.89 | 0 | 0 | 0 | 0 |
| 48-49 | 1.43 | 4 | 0 | 0 | 0.97 |
| 48-58 | 1.05 | 3 | 0 | 0 | 0.89 |
| 49-50 | 0.89 | 2 | 0 | 0 | 0.88 |
| 51-55 | 1.97 | 0 | 0 | 0 | 0 |
| 52-53 | 1.9 | 2 | 0 | 0 | 0.89 |
| 52-54 | 1.9 | 2 | 0 | 0 | 0.93 |
| 53-55 | 1.82 | 0 | 0 | 0 | 0 |
| 53-56 | 1.89 | 4 | 0 | 0 | 0.94 |
| 54-56 | 2.2 | 2 | 0 | 0 | 0.9 |
| 54-57 | 0.93 | 4 | 0 | 0 | 0.92 |
| 55-66 | 1.1 | 0 | 0 | 1 | 0.5 |
| 56-66 | 1.25 | 0 | 0 | 0 | 0 |
| 56-70 | 1.19 | 0 | 0 | 0 | 0 |
| 57-58 | 0.65 | 2 | 0 | 0 | 0.78 |
| 57-70 | 1.8 | 0 | 0 | 0 | 0 |
| 58-59 | 1.1 | 0 | 1 | 0 | 0.78 |
| 58-72 | 1.4 | 0 | 2 | 0 | 0.57 |
| 59-60 | 1.4 | 0 | 0 | 0 | 0 |
| 59-79 | 1.62 | 0 | 0 | 3 | 0.78 |
| 60-61 | 1.63 | 0 | 0 | 0 | 0 |
| 60-62 | 1.4 | 0 | 0 | 0 | 0 |
| 62-63 | 1.3 | 0 | 0 | 0 | 0 |
| 62-80 | 1.6 | 0 | 2 | 0 | 0.76 |
| 63-64 | 1 | 0 | 0 | 0 | 0 |
| 64-65 | 0.9 | 0 | 0 | 0 | 0 |
| 64-82 | 1.2 | 2 | 0 | 0 | 0.9 |
| 64-87 | 1.3 | 0 | 0 | 0 | 0 |
| 65-84 | 1.7 | 0 | 0 | 0 | 0 |
| 66-67 | 1.02 | 0 | 0 | 0 | 0 |
| 66-69 | 1.02 | 0 | 1 | 0 | 0.7 |
| 67-68 | 1.9 | 0 | 0 | 0 | 0 |
| 68-76 | 1.79 | 0 | 0 | 0 | 0 |
| 69-70 | 1.76 | 0 | 0 | 2 | 0.67 |
| 69-71 | 1.69 | 0 | 0 | 0 | 0 |
| 69-75 | 1.95 | 4 | 0 | 0 | 0.89 |
| 70-72 | 1.05 | 0 | 1 | 0 | 0.78 |
| 71-73 | 2.3 | 0 | 0 | 0 | 0 |
| 72-73 | 1.21 | 0 | 2 | 0 | 0.74 |
| 73-74 | 1.25 | 0 | 0 | 1 | 0.32 |
| 74-75 | 2.52 | 0 | 0 | 0 | 0 |
| 74-77 | 2.1 | 0 | 0 | 2 | 0.56 |
| 74-80 | 2.9 | 0 | 0 | 3 | 0.67 |
| 75-77 | 1.92 | 4 | 0 | 0 | 0.97 |
| 76-77 | 1.68 | 0 | 0 | 0 | 0 |
| 77-78 | 2.6 | 4 | 0 | 0 | 0.96 |
| 78-81 | 2 | 2 | 0 | 0 | 0.92 |
| 79-80 | 1.97 | 0 | 2 | 0 | 0.59 |
| 80-81 | 2.01 | 4 | 0 | 0 | 0.95 |
| 81-82 | 2 | 4 | 0 | 0 | 0.94 |
| 81-83 | 2.32 | 4 | 0 | 0 | 0.96 |
| 82-83 | 1.87 | 3 | 0 | 0 | 0.89 |
| 83-87 | 1.62 | 0 | 0 | 0 | 0 |
| 84-85 | 1.82 | 0 | 0 | 0 | 0 |
| 84-86 | 1.3 | 0 | 0 | 0 | 0 |
| 86-87 | 2.05 | 0 | 0 | 0 | 0 |

TABLE VII
Node PARAMETERS OF UTN

| Node Number | Node Types | Load/MW | Active Output/MW |
|---|---|---|---|
| 1 | pq | 0 | 0 |
| 2 | pq | 0 | 0 |
| 3 | pq | 342 | 0 |
| 4 | pq | 385 | 0 |
| 5 | pq | 0 | 0 |
| 6 | pq | 0 | 0 |
| 7 | pq | 233.8 | 0 |
| 8 | pq | 268.5 | 0 |
| 9 | pq | 0 | 0 |
| 10 | pq | 0 | 0 |
| 11 | pq | 0 | 0 |
| 12 | pq | 287.5 | 0 |
| 13 | pq | 0 | 0 |
| 14 | pq | 0 | 0 |
| 15 | pq | 220 | 0 |

| | | | |
|---|---|---|---|
| 16 | pq | 329 | 0 |
| 17 | pq | 0 | 0 |
| 18 | pq | 258 | 0 |
| 19 | pq | 0 | 0 |
| 20 | pq | 228 | 0 |
| 21 | pq | 274 | 0 |
| 22 | pq | 385 | 0 |
| 23 | pq | 247.5 | 0 |
| 24 | pq | 368.6 | 0 |
| 25 | pq | 324 | 0 |
| 26 | pq | 339 | 0 |
| 27 | pq | 261.5 | 0 |
| 28 | pq | 306 | 0 |
| 29 | pq | 583.5 | 0 |
| 30 | pq | 0 | 600 |
| 31 | vθ | 0 | 0 |
| 32 | pv | 9.5 | 750 |
| 33 | pv | 0 | 850 |
| 34 | pv | 0 | 508 |
| 35 | pv | 0 | 650 |
| 36 | pv | 0 | 250 |
| 37 | pv | 0 | 540 |
| 38 | pv | 0 | 830 |
| 39 | pv | 0 | 868 |

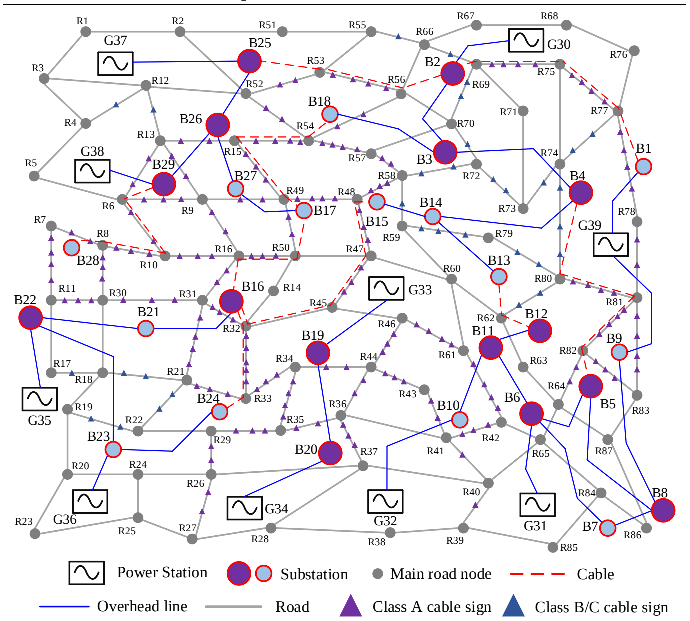


**Fig. B1 The coupling network between UTN and the road network of the case**