MGs with deep penetration of renewable energy affect the operation of DN system, due to stochastic behaviour of wind speed and solar radiation. Besides, in some countries like China, the DN and MGs usually belong to different companies and/or share different interests. For example, the distribution network operator focuses more on the safe and economic operation of itself, and it expects the MGs to participate more in the economic dispatch and peak load shifting. However, the MGs care more about maximizing their own profits.

Bi-level optimization model

Step 1: DN optimizes its power flow and gives an expected exchange power curve $P_{EP}^1$ for each MG.

Step 2: Each MG decides whether to meet the expected exchange power curve and obtains optimal exchange power curve $P_{EP}^0$.

Step 3: The electricity price is determined by match degree between $P_{EP}^0$ and $P_{EP}^1$, based on the Euclid approach degree method, which can be defined as

$$N = 1 - \frac{1}{\sqrt{\sum_{t=1}^{T_{op}} (A_i \cdot t - B_i \cdot i)^2}}$$

$$C_{EP}^1 = C_{EP} (\alpha - N)$$

$$C_{EP}^2 = C_{EP} (\beta + N)$$

Where, $\alpha$ and $\beta$ are 1.5 and 0.5, respectively.

Results

Scenario 1: The base case that the DN operates without MGs.

Scenario 2: Separate operation of the DN and MGs.

Scenario 3: Co-operation of the DN and MGs with bi-level model.

Conclusion

- The new bi-level model provides a scheme to find the co-optimization solution of the DN with multi-MGs.
- It proposed a dynamic electricity pricing strategy, which can make a win-win game for both DN and MGs.
- The risk brought by intermittent and stochastic characteristic of renewable energy can be greatly reduced by encouraging the MGs to participate in the operation of DN with an incentive.