**Appendix 1: KKT Transformation**

The transformation process of (heat load) is as follows.

The MELA model’s objective function and constraints are built around the total heat load. Although the model also includes nodal heat load constraints (57), nodal loads are not direct optimization variables but are calculated are calculated proportionally after the total load is optimized. In other words, nodal load constraints in the MELA model do not affect the MELA model’s objective function value or the optimal total load. Therefore, for computational efficiency, we omit these constraints when deriving the KKT conditions and retain them only as original constraints.

The heat load objective function and its KKT condition-related constraints include (71)-(72).

 (71)

 (72)

Based on the objective function and constraints mentioned above, write the corresponding Lagrangian function 𝑟. After completing the formulation of the Lagrangian function for the lower-level model, the corresponding KKT (Karush-Kuhn-Tucker) conditions are obtained:

 (73)

Based on the KKT conditions (73), the objective function non-convex term  can be converted into a convex function:

 (74)