Port of spain distributed energy systems

Figure 10.1 illustrates a general structure of PIES coupling LS and ES. The ES consists of energy equipment, electricity and natural gas network. Electricity and natural are purchased from main grid and natural gas wells, and then are transmitted via electric lines and gas pipelines. Various energy technologies including gas turbine (GT), power to gas (P2G), energy storage system (ESS) and photovoltaic (PV) are integrated in the two energy supply networks. The ES feed all the energy demands from docked ship and QCs, fixed electricity and natural gas loads.

The LS comprises ships and QCs, as Fig. 10.2 shows. In the respect of logistic transportation, QCs are assigned for docked ships to load and unload containers on ships. The arrival ships anchor to wait or dock at free berth according to berth allocation plan. After loading/unloading tasks are completed, the ships leave the seaport. In the terms of energy consumption, electrified QCs and docked ships are support by electrical networks. The QCs are directly connected with certain electrical nodes while the docked ships are linked via shore-side power interfaces (cold-ironing).

The docking status Xbst is a three-dimensional binary variable that combines berthing position Bs, ship number s and berthing duration together. The value of Xbst is 1 if the ship docks at berth b at time interval t, otherwise, it equals to 0. Equation (10.1) has two implications, (1) ensure that the berthing position do not change in the whole scheduling period once it is allocated; (2) the value of Xbst remains 1 only during docking period.

The relationship between arrival time, docking start time and departure time are constrained by Eqs. (10.2-10.3). The docking start time should be greater than or equal to ship arrival time. The departure time should be greater than docking start time and less than or equal to latest departure time.

The QCs are used to load/unload containers on ships and directly influence the berthing duration of ships. A time-variant QC assignments model is considered in this book in order to increase the flexibility of logistic operation. That means the QCs allocated to a ship are not fixed from a period to another period of time. The QC assignment constraints are formulated as follows:

Equations (10.1-10.18) limit the behaviors of ships and QCs within allowed range to ensure normal logistics transportation operations. However, the decision of berth allocation and QC assignment should also consider energy systems constraints.

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