Market Driven Systems (FRTN20)
Exercise 7
Utility Disturbance Management
Last updated: 2014

The following introduction is the base for all the questions in this exercise.

A flowchart of the product flow at a site is given in Figure 1. Some information about the products of the site is given in Table 1

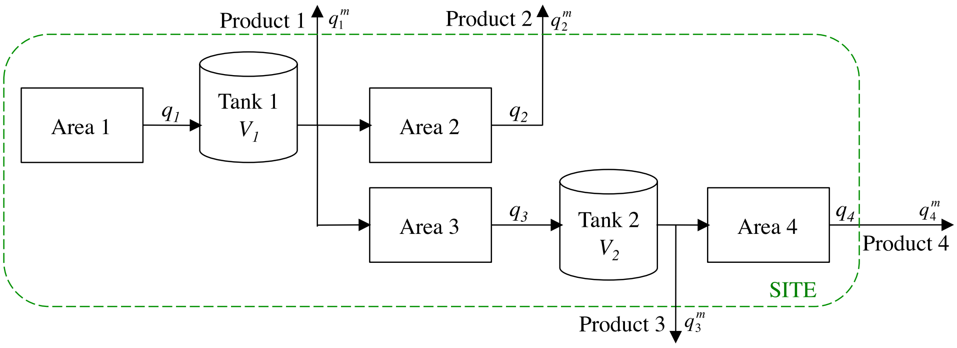


Figure 1 Flowchart of the product flow at a site.

Table 1 Product data

	Flow to market at max. production (m^3/h)	Contribution margin (kr/m^3)
Product 1	3	2
Product 2	2	3
Product 3	0	6
Product 4	2	6

The site uses three utilities; steam, cooling water and electricity. Steam is required at area 2 and 3, cooling water at area 1 and 3, and electricity is required at all areas. Measurements of the steam pressure, the cooling water temperature, and electricity operation (on/off) are given below for 80 minutes of operation. The sample time is 10 minutes.

$$\begin{aligned}
\text{steam} &= [30\ \ 29\ \ 32\ \ 30\ \ 28\ \ 27\ \ 29\ \ 32] \\
\text{cooling water} &= [20\ \ 22\ \ 26\ \ 22\ \ 28\ \ 27\ \ 24\ \ 25] \\
\text{electricity} &= [1\ \ 1\ \ 1\ \ 1\ \ 1\ \ 1\ \ 0\ \ 1]
\end{aligned}$$

Disturbance limits for the utilities at the site gave been found to be:

Steam :	pressure $<$ 30 bar
Cooling water :	temperature $>$ 25°C
Electricity :	on/off

Define site structure and use of utilities

1. Give a representation of the site structure using the area dependence matrix, A_d.

2. Give a representation of which utilities that are required in each area using the area-utility matrix, A_u.

3. The steam and cooling water utilities are both dependent on electricity. Steam and cooling water are independent. Electricity does not rely on the operation of any of the other utilities. Draw flowchart showing the interdependence between the utilities and give the utility dependence matrix, U_d.

4. Give the utility operation matrix, i.e. the matrix that describes which utilities that have operated correctly at each sample point.

5. Remove utility dependence from the utility operation matrix and give the resulting utility operation matrix, U_{ud}.

Calculate key performance indicators

6. Compute utility availability using

a. the utility operation matrix before removing utility dependence (U).

b. the utility operation matrix when utility dependence is removed (U_{ud}). How does the availabilities change when taking utility availability into account?

7. Which area(s) have the lowest availability, if both disturbances in utilities and the connections of production areas at the site are considered?

Hint:

$$A_{dir} = \mathbf{1}\mathbf{1}^T + \text{sign}\left(A_u(U - \mathbf{1}\mathbf{1}^T)\right) = \begin{bmatrix} 1 & 1 & 0 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 \end{bmatrix}$$

$$A_{tot} = \mathbf{1}\mathbf{1}^T + \text{sign}\left(A_d(A_{dir} - \mathbf{1}\mathbf{1}^T)\right) = \begin{bmatrix} 1 & 1 & 0 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Estimate losses using on/off production modeling

8. Which product seems to stand for the greatest total revenue loss?

9. The utility availabilities computed in problem 6 seem to be representative for how the site has operated during the entire year. The head of the maintenance department would like to use this information to plan the maintenance schedule for next year. What utility would you advice him to focus on? Motivate your answer.

Define model and constraints for continuous production modeling

10. Define the mass balance equations for the site (figure 1). Assume that the inflow to an area is proportional to the outflow of the area, i.e. $q_j^{\text{in}} = q_j y_{ij}$, where y_{ij} is a constant conversion factor.

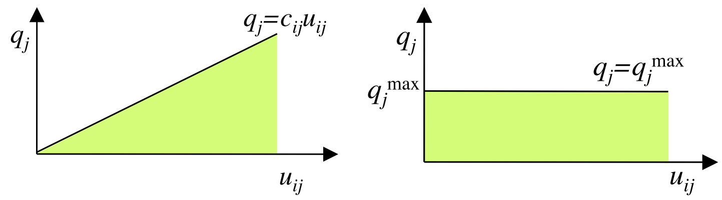
11. Assume that all utilities at the site operate correctly, such that these do not impose any constraints on the production. Mention some other constraints that are needed to define a realistic model of the site.

12. Assume that the production in area i is limited by the supply of utility j to that area according to

$$q_i \leq c_{ij} u_{ij} \tag{1}$$

for continuous utilities. This constraint is visualized in figure 2(a).

For on/off type utilities, all areas that require a utility may produce at maximum speed if the utility is available, and can not produce otherwise. This constraint is visualized in figure 2(b).



(a) Continuous utility (b) On/off utility

Figure 2 Utilities' constraints on production.

Assume also that all utilities are shared by the production areas that require them:

$$\sum_{j \in \mathcal{M}_i} u_{ij}(t) \leq U_i(t), \quad i = 1, \ldots, n_u \tag{2}$$

where $u_{ij}(t)$ is the amount of utility i that is assigned to area j at time t, $U_i(t)$ is the total amount of utility i available at time t, and n_u the number of utilities used at the site. $\mathcal{M}_i$ is the set of areas that require utility i.

Assume that equality holds in (1) and write down the constraints the utilities at the site pose on the production rates of the areas. Consider steam and cooling water to be continuous utilities and electricity to be an on/off type of utility.