

**MIDTERM REVIEW**  
**Wednesday, March 16, 2011**  
**Regular class**

**MIDTERM EXAM**  
**Open book and notes**  
**Saturday, March 19, 2011**  
**8:00 am - 12:00 pm**  
**Room NC 1325**

## Assignment 8. Due 03/28/11.

17. Draw a network representation of the maintenance planning model for 3 power units  $p_1$ ,  $p_2$  and  $p_3$  with

|                             |                                                |            |            |
|-----------------------------|------------------------------------------------|------------|------------|
| demanded power              | $w_1 = 5,$                                     | $w_2 = 3,$ | $w_3 = 3,$ |
| fall in the operating power | $h_1 = 3,$                                     | $h_2 = 2,$ | $h_3 = 2,$ |
| required duration           | $x_1^{\max} = 3, x_2^{\max} = x_3^{\max} = 2.$ |            |            |

The planning period  $T_{\max} = 4$  days with the power reserve

$f(1) = 4, f(2) = 5, f(3) = 7, f(4) = 2.$

Explain your network.

## Maintenance Planning as ABG: Artificial Agents

(For more details see Chapter 7 of the book on LG)

Assume that a power-producing company is going to set up a maintenance plan for the power-producing equipment for a given planning period  $T_{\max}$ , e.g., month, year. There exists an array of  $m$  demands for maintenance work of power units. The problem is to satisfy these demands. To do that we must include the maintenance work for all the demanded units into the plan, i.e., to schedule maintenance. A maintenance work of a power unit causes turning off of this unit, and, consequently, a loss of generating power in the system. Thus, it is impossible to meet all the demands because of problem constraints, which is basically the power reserve, i.e., the amount of power to be lost without turning off customers. This amount varies daily.

Each demand requests maintenance work for one power unit ( $j$ -th unit) and contains three attributes:

- $w_j$ , is a demanded power of the unit (power production capacity);
- $h_j$ , is a loss in the operating power of the energy-producing system because of maintenance of this unit (resources requirements); and
- $x_j^{\max}$  is a required duration of maintenance.

For simplicity, we neglect the rest of the demand's attributes. For the same reason we specify the only type of constraints - function  $f(i)$  of power reserve for the power-producing system, where  $i$  is the number of a day of the planning period. On the  $i$ -th day of the planning period the total loss in the operating power, because of the maintenance of some power units, can not be greater than the value  $f(i)$ . The values of all the parameters are positive integer numbers.

The optimum criterion of the plan is the maximum total demanded power of the units being maintained.

## Maintenance Planning Model

2 power units  $p_1$  and  $p_2$  with

demanded power

$$w_1 = 5$$

$$w_2 = 2$$

operating power loss

$$h_1 = 3$$

$$h_2 = 2$$

required duration

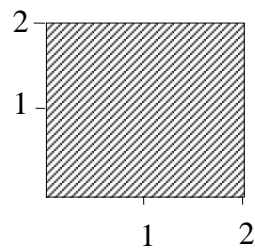
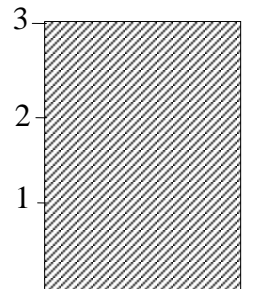
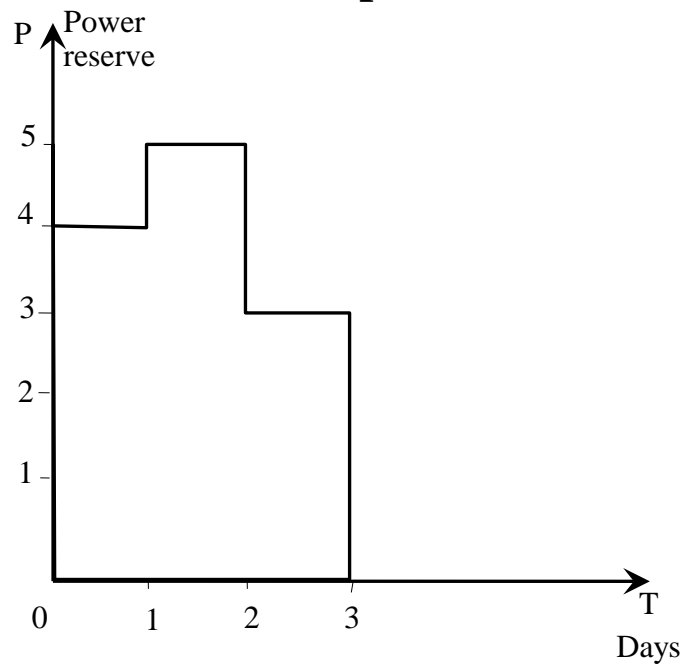
$$x_1^{\max} = 2$$

$$x_2^{\max} = 2$$

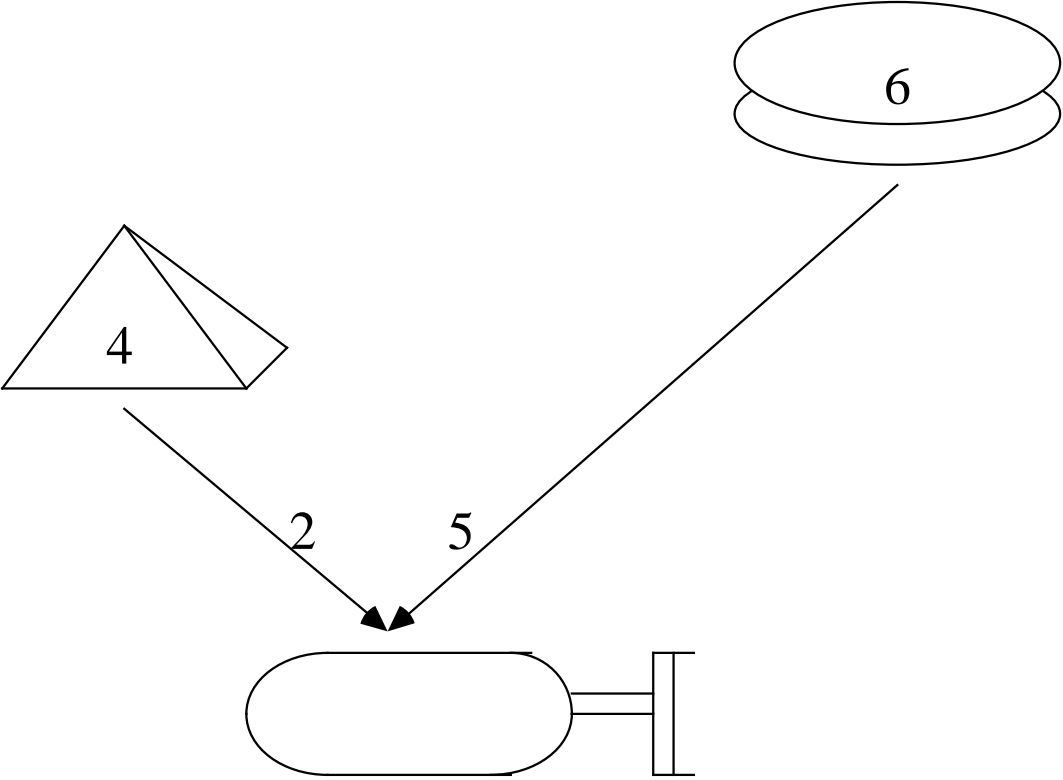
The planning period  $T_{\max} = 3$  days with the power reserve

$$f(1) = 4, f(2) = 5, f(3) = 3$$

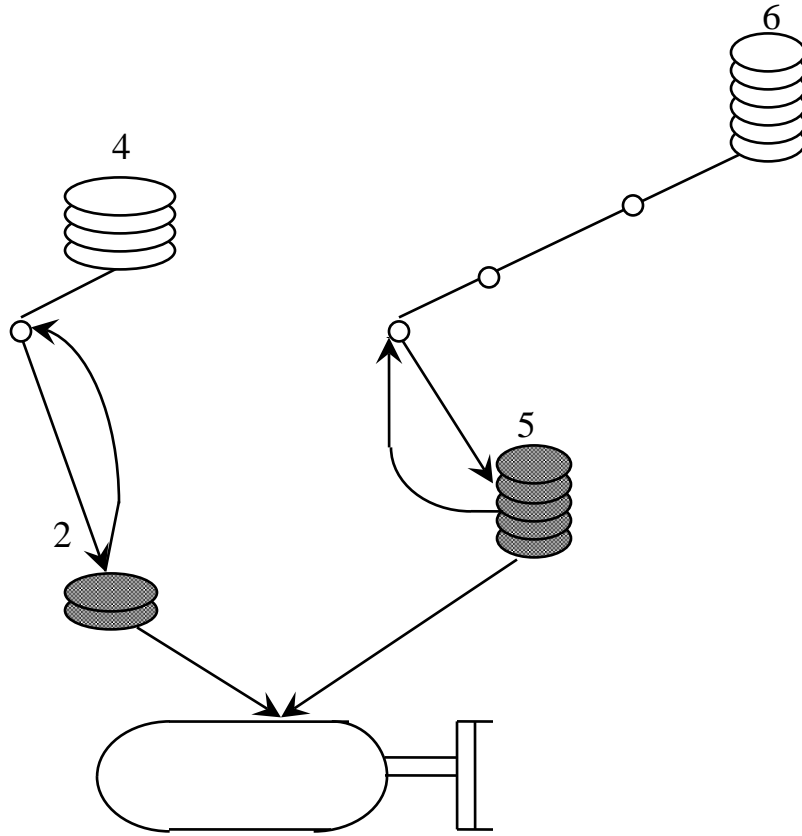
### Conventional Representation



# Resources Requirements for Maintenance Work



## Resources Requirements as Opposing Agent



## Network Representation (draft)

2 power units  $p_1$  and  $p_2$  with

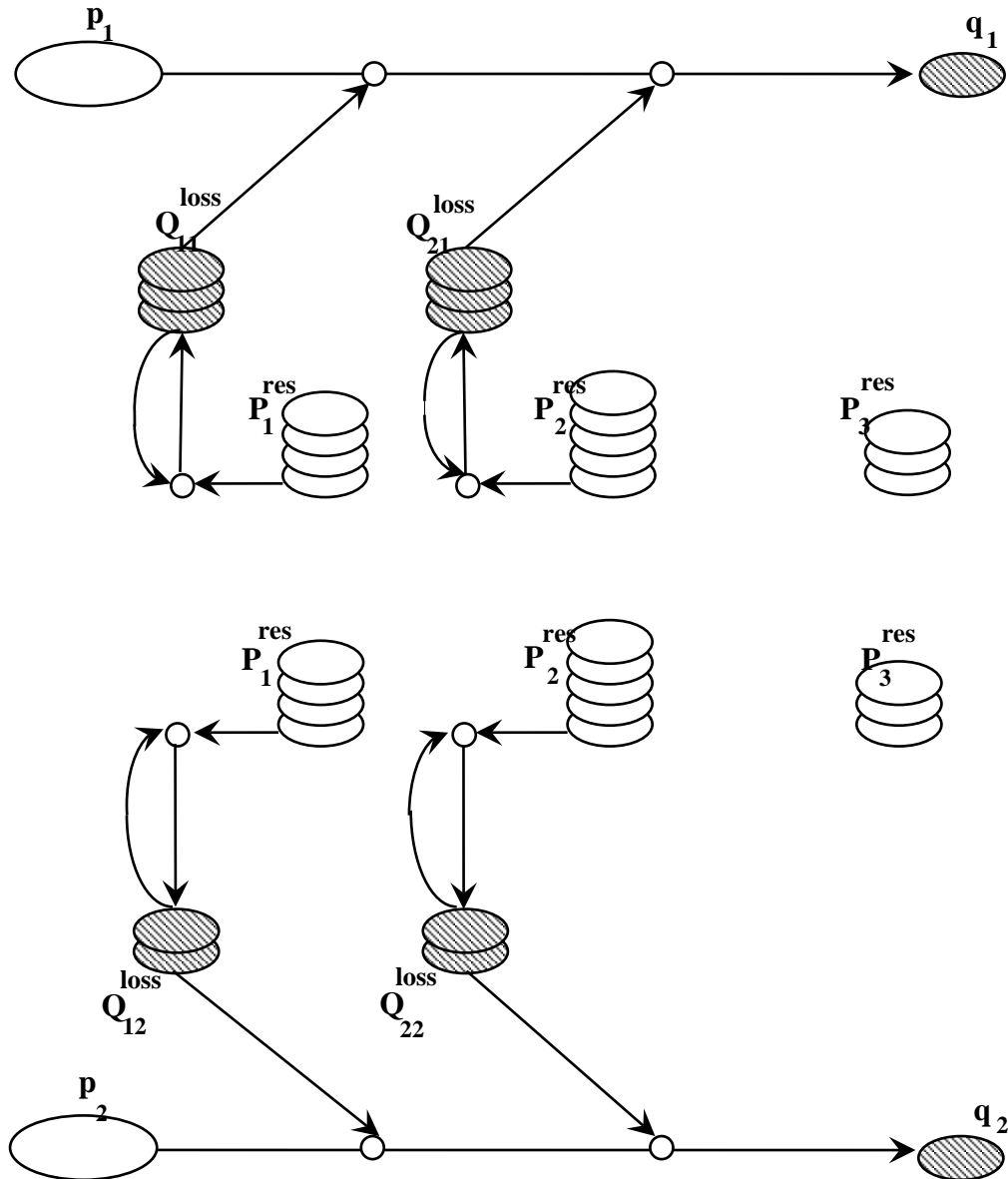
demanded power  $w_1 = 5, w_2 = 2$

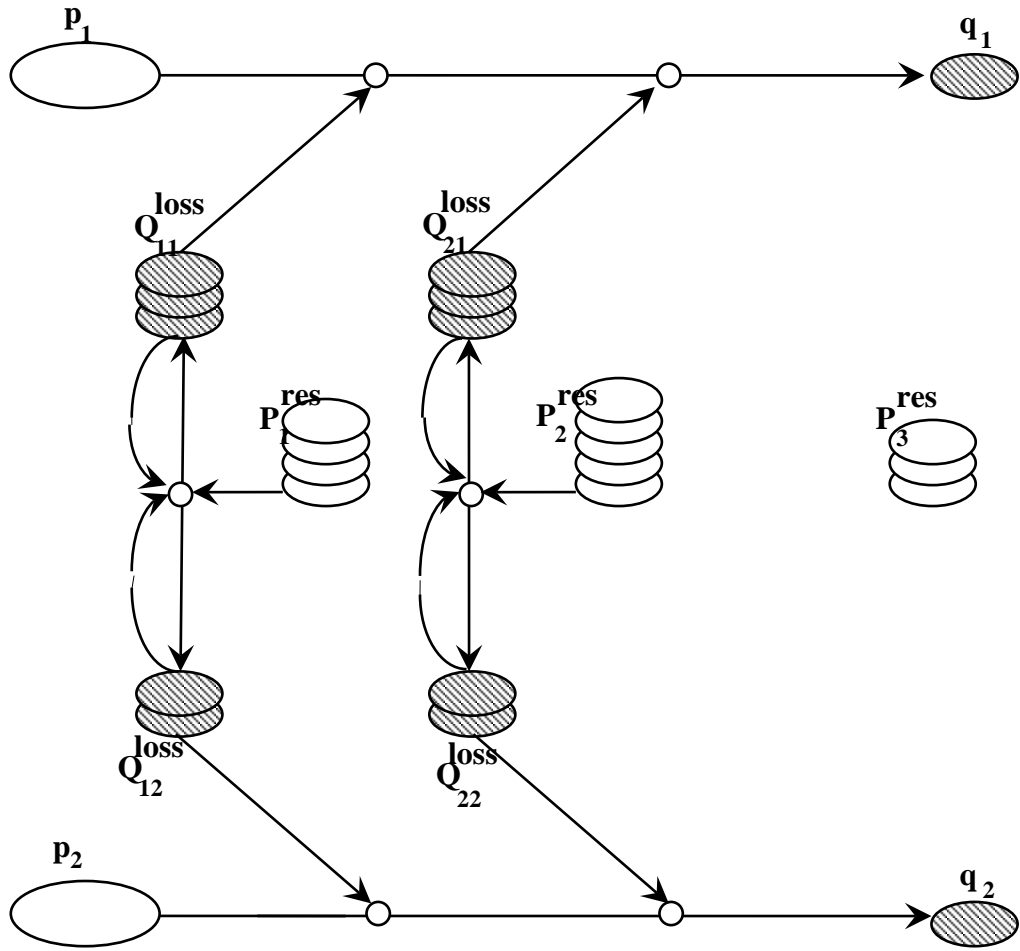
oper. power loss  $h_1 = 3, h_2 = 2$

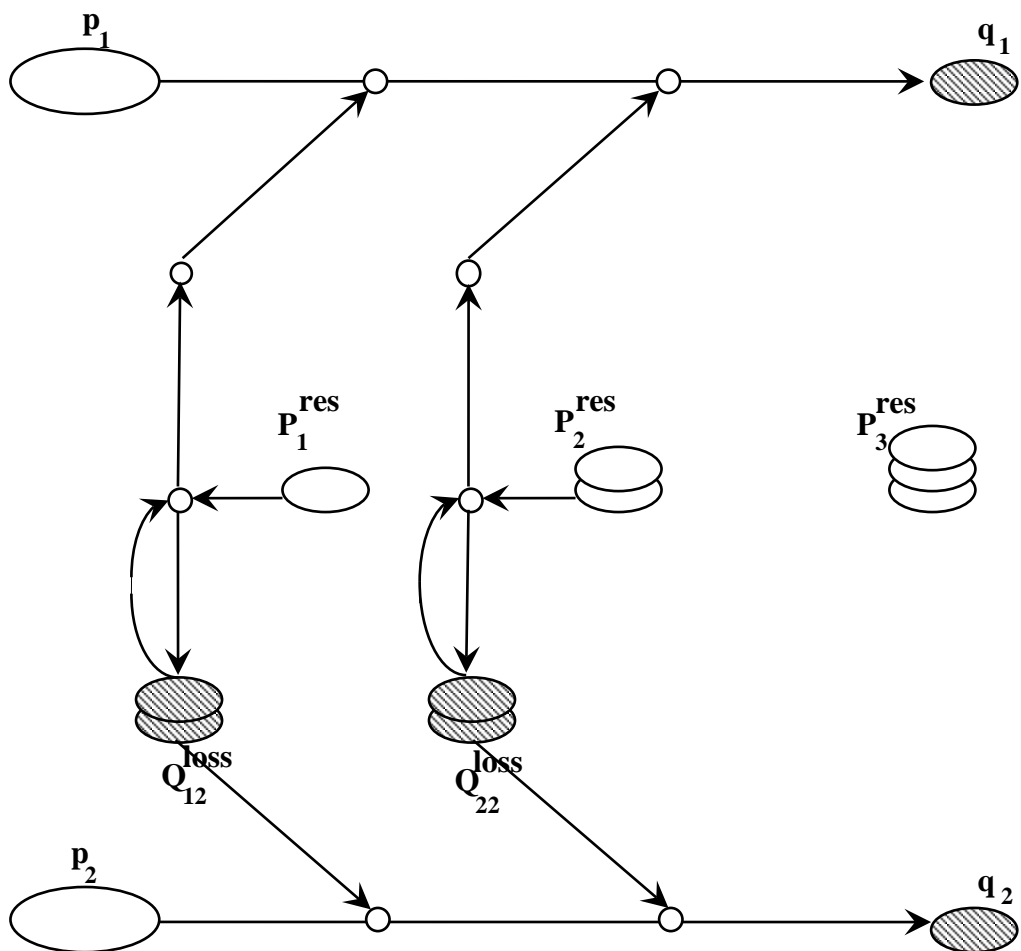
required duration  $x_1^{\max} = x_2^{\max} = 2$

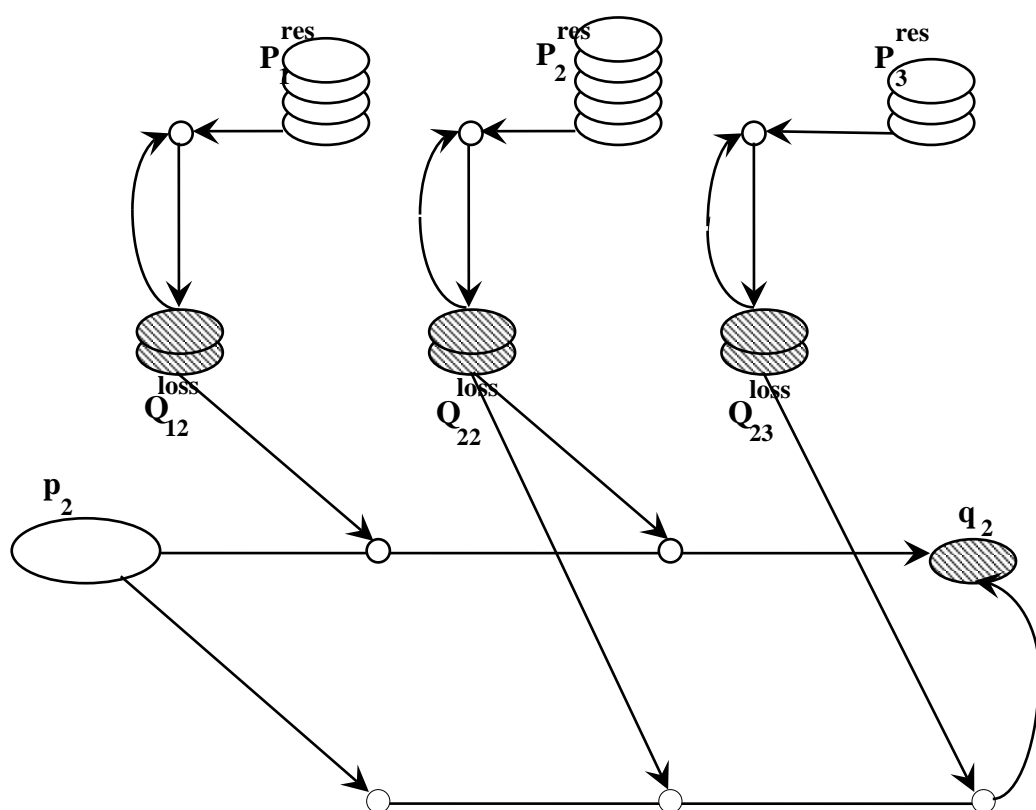
The planning period  $T_{\max} = 3$  days with the power reserve

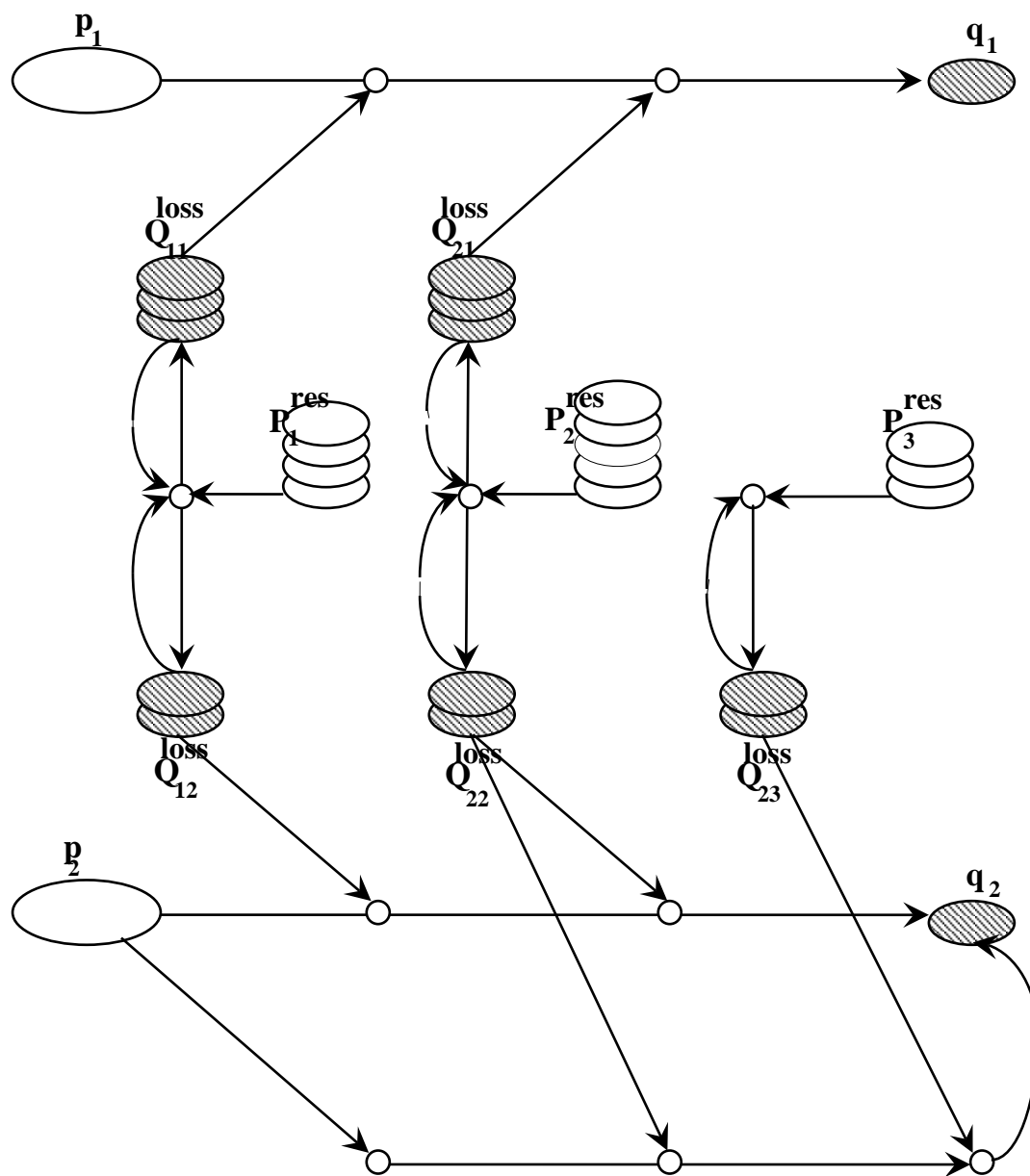
$f(1) = 4, f(2) = 5, f(3) = 3$



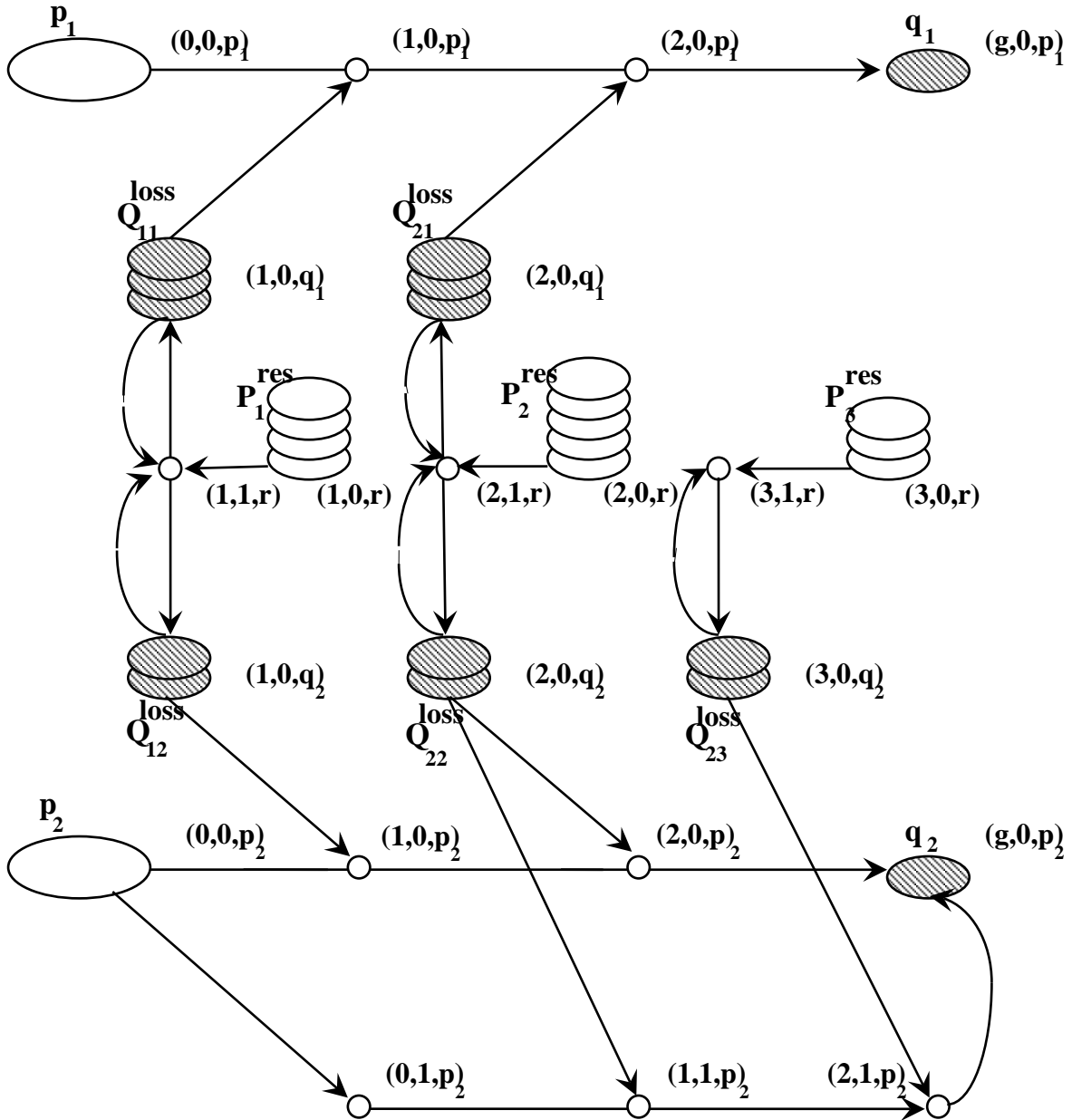








## Heuristic Network for Maintenance Planning



## Class of Problems

### ABG

is the following eight-tuple

$$\langle \mathbf{X}, \mathbf{P}, \mathbf{R}_p, \{\mathbf{ON}\}, v, \mathbf{S}_i, \mathbf{S}_t, \mathbf{TR} \rangle$$

$\mathbf{X} = \{\mathbf{x}_i\}$  is a finite set of *points*;

$\mathbf{P} = \{\mathbf{p}_i\}$  is a finite set of *elements*;  $\mathbf{P} = \mathbf{P}_1 \cup \mathbf{P}_2, \mathbf{P}_1 \cap \mathbf{P}_2 = \emptyset$ ;

$\mathbf{R}_p(\mathbf{x}, \mathbf{y})$  is a family of binary relations of *reachability* in  $\mathbf{X}$   
 $(\mathbf{x} \in \mathbf{X}, \mathbf{y} \in \mathbf{X}, \mathbf{p} \in \mathbf{P})$ ;  $\mathbf{y}$  is *reachable* from  $\mathbf{x}$  for  $\mathbf{p}$ ;

$\mathbf{ON}(\mathbf{p}) = \mathbf{x}$  is a partial function of *placement* of elements  $\mathbf{P}$  into  $\mathbf{X}$ ;

$v > 0$  is a real function,  $v(\mathbf{p}_i)$  are the *values* of elements;

$\mathbf{S}_i$  is a set of *initial* states of the system,  
 a certain set of formulas  $\{\mathbf{ON}(\mathbf{p}_i) = \mathbf{x}_i\}$ ;

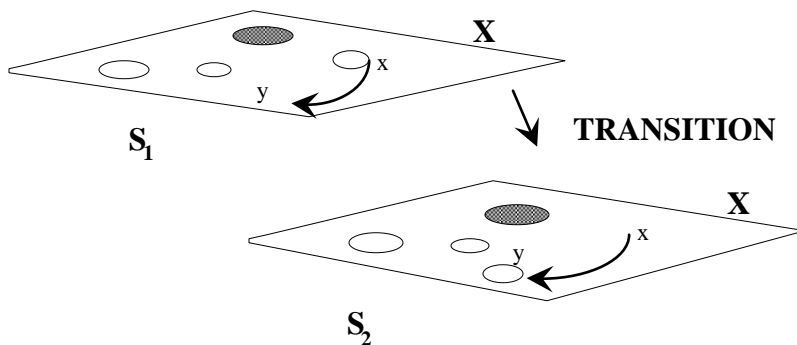
$\mathbf{S}_t$  is a set *target* states of the system (as  $\mathbf{S}_i$ );

$\mathbf{TR}$  is a set of operators **TRANSITION**( $\mathbf{p}, \mathbf{x}, \mathbf{y}$ ) for transition of the system from one state to another described as follows

**precondition:**  $(\mathbf{ON}(\mathbf{p}) = \mathbf{x}) \wedge \mathbf{R}_p(\mathbf{x}, \mathbf{y})$

**delete:**  $\mathbf{ON}(\mathbf{p}) = \mathbf{x}, \mathbf{ON}(\mathbf{q}) = \mathbf{y}$

**add:**  $\mathbf{ON}(\mathbf{p}) = \mathbf{y}$



Formal representation of the ABG for the maintenance problem is as follows:

$$\mathbf{X} = (\mathbf{Y} \cup \{\mathbf{g}\}) \times \mathbf{Y} \times (\mathbf{P}_{\text{dem}} \cup \mathbf{Q}_{\text{dem}} \cup \{\mathbf{r}\}),$$

where  $\mathbf{Y} = \{0, 1, \dots, T_{\text{max}}\}$ ,

$\mathbf{P}_{\text{dem}}$  is the set of power units included in the demands,  $|\mathbf{P}_{\text{dem}}|$  is the number of demands. A duplicate set  $\mathbf{Q}_{\text{dem}}$  of the elements  $q_j$  is introduced, and one-to-one correspondence  $q_j \leftrightarrow p_j$  is established between elements of  $\mathbf{Q}_{\text{dem}}$  and  $\mathbf{P}_{\text{dem}}$

$$\mathbf{P} = \mathbf{P}_1 \cup \mathbf{P}_2, \mathbf{P}_1 \text{ and } \mathbf{P}_2 \text{ are not intersected and}$$

$$\mathbf{P}_1 = \mathbf{P}_{\text{dem}} \cup \mathbf{P}_{\text{reserve}}, \quad \mathbf{P}_2 = \mathbf{Q}_{\text{dem}} \cup \mathbf{Q}_{\text{loss}},$$

$$\mathbf{P}_{\text{reserve}} = \bigcup_{i=1}^{T_{\text{max}}} \mathbf{P}_i^{\text{res}}, \quad \mathbf{Q}_{\text{loss}} = \bigcup_{i=1}^{T_{\text{max}}} \bigcup_{j=1}^{|\mathbf{Q}_{\text{dem}}|} \mathbf{Q}_{ij}^{\text{loss}}$$

To show the number of elements  $|\mathbf{P}_{\text{reserve}}|$  and  $|\mathbf{Q}_{\text{loss}}|$  we have to define  $\mathbf{v}_0$ . It is the quantum of power loss, the common factor of all values  $f(i)$  of power reserve and all values  $h_j$  of power loss (for all demanded units); for example,  $\mathbf{v}_0=1$  Megawatt. We can now determine  $|\mathbf{P}_{\text{reserve}}|$  and  $|\mathbf{Q}_{\text{loss}}|$ , having given  $|\mathbf{P}_i^{\text{res}}|$  and  $|\mathbf{Q}_{ij}^{\text{loss}}|$ . Thus,

$$|\mathbf{P}_i^{\text{res}}| = f(i)/\mathbf{v}_0 \quad \text{and} \quad |\mathbf{Q}_{ij}^{\text{loss}}| = h_j/\mathbf{v}_0.$$