Part D

The maintenance schedule has the following constraints:

$$\begin{cases} 4 * 100\ MW\ units\ , each\ requires\ a\ maintenance\ of\ 4\ weeks = 2\ periods \\ 6 * 300\ MW\ units\ , each\ requires\ a\ maintenance\ of\ 6\ weeks = 3\ periods \\ \quad three\ crews\ available\ to\ carry\ out\ the\ maintenance \end{cases}$$

Method 1: Reserved-based Scheduling

The first method used here is based on the reserve. It was chosen, since as mentioned in part b, the reserve-based analysis serves as a good starting point. The reserve is chosen in this study to be the difference between the peak demand and the available capacity that is not undergoing maintenance at this period. We aim to level the reserve, so we try to minimize the absolute value error in the reserve values.

A mixed integer linear programming (MILP) is formulated as follows:

x_i: $the\ number\ of\ 300\ MW\ units\ that\ start\ their\ maintenance\ at\ period\ i$
y_i: $the\ number\ of\ 100\ MW\ units\ that\ start\ their\ maintenance\ at\ period\ i$
m_i: $the\ number\ of\ 300\ MW\ that\ are\ undergoing\ maintenance\ at\ period\ i$
n_i: $the\ number\ of\ 100\ MW\ units\ that\ are\ undergoing\ maintenance\ at\ period\ i$
U_i: $a\ set\ of\ positive\ continuous\ dummy\ variables\ to\ linearize\ the\ absolute\ value$
R_i: $the\ amount\ of\ reserve\ at\ period\ i$
D_i: $the\ peak\ demand\ at\ period\ i$
$R_{average}$: $the\ average\ reserve$

$$Minimize \sum U_i$$
$s.t.$
$\forall i\ \ (m_i + n_i) \leq 3\ (no\ more\ than\ 3\ units\ maintained\ at\ a\ given\ period$
$\sum xi = 6\ (6\ 300\ MW\ units\ must\ be\ maintained)$
$\sum y_i = 4\ (4\ 100\ MW\ units\ must\ be\ maintained)$
$\forall i\ m_i = x_i + x_{i-1} + x_{i-2}\ where\ x_{-1} = 0\ and\ x_{-2} = 0\ (definition\ of\ m)$
$\forall i\ n_i = y_i + y_{i-1}\ where\ y_{-1} = 0\ (definition\ of\ n)$
$\forall i\ R_i = 2{,}200 - 300m_i - 100n_i - D_i (definition\ of\ R)$
$\forall i\ R_i \geq 2 \times 300\ (amount\ of\ reserve\ at\ each\ period\ greater\ than\ sum\ of\ largest\ 2\ units)$
$x_{11} = 0\ \&\ x_{12} = 0\ (maintenance\ of\ 300\ MW\ cannot\ be\ started\ beyond\ 10th\ period\ to\ finish\ )$
$y_{12} = 0\ (maintenance\ of\ 100\ MW\ cannot\ be\ started\ beyond\ 11th\ period\ to\ finish\ )$
$\forall i\ \left(R_{average} - R_i\right) < U_i\ \&\ \left(R_{average} - R_i\right) > -U_i\ (as\ if\ \left|R_{average} - R_i\right| < U_i)$
$$\left(Minimize \sum U_i\ as\ if\ minimizing \sum \left|R_{average} - R_i\right|\right)$$

The optimization problem has been solved using the “intlingprog” function available in MATLAB.

The result can be shown plotted in figure 7. It can be shown that the reserve is uniform.

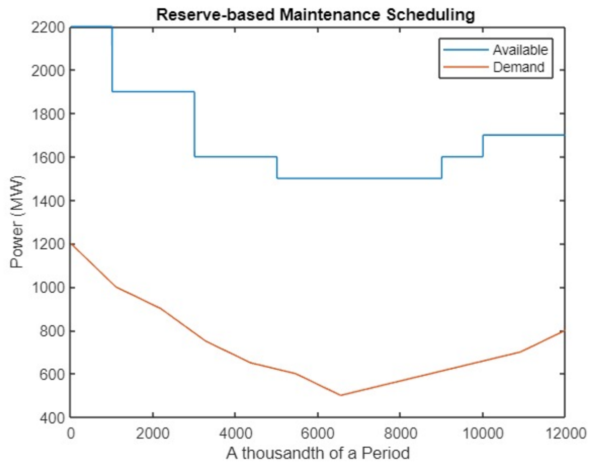

Figure 7: Reserve-based Maintenance Scheduling

The number of units that are under maintenance in each period is illustrated in the table below:

Period	Number of 300 units under maintenance	Number of 100 units under maintenance	Total number of units under maintenance
1	0	0	0
2	1	0	1
3	1	0	1
4	2	0	2
5	2	0	2
6	2	1	3
7	2	1	3
8	2	1	3
9	2	1	3
10	2	0	2
11	1	2	3
12	1	2	3

Figure 8: Maintenance Table for Reserve-Based

The total power lost, and the remaining reserve can be inferred from figure 8. The results are represented in figure 9.

Period	Total power lost under maintenance (MW)	Reserve (MW)
1	0	1000
2	300	900
3	300	1000
4	600	850
5	600	950
6	700	900
7	700	1000
8	700	950
9	700	900
10	600	950
11	500	1000
12	500	900

Figure 9: Power lost and Reserve of Each Period

From figure 9, it is shown that the minimum reserved power is kept greater than two of the largest units (2*300 MW).

A variation of that would be to level the percentage reserve rather than the difference reserve. The results are shown in figure 10.

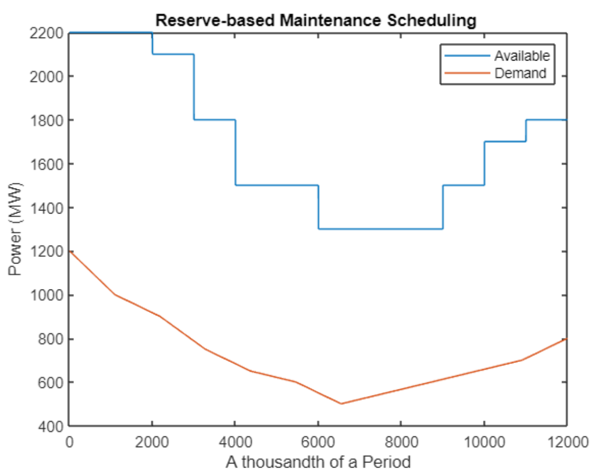

Figure 10: Percentage Reserve Maintenance Scheduling

The number of units that are under maintenance in each period is illustrated in the table below:

Period	Number of 300 units under maintenance	Number of 100 units under maintenance	Total number of units under maintenance
1	0	0	0
2	0	0	0
3	0	1	1
4	1	1	2
5	2	1	3
6	2	1	3
7	3	0	3
8	3	0	3
9	3	0	3
10	2	1	3
11	1	2	3
12	1	1	2

Figure 11: Maintenance Table for % Reserve-Based

The total power lost, and the remaining percentage reserve are represented in figure 12.

Period	Total power lost under maintenance (MW)	Percentage Reserve (%)
1	0	83.33
2	0	120
3	100	133
4	400	140
5	700	130
6	700	150
7	900	160
8	900	136
9	900	116.7
10	700	130.7
11	500	142.8
12	400	125

Figure 12: Power lost and % Reserve of Each Period

Method 2: Risk-based

A different, greedy approach has been used to tackle the risk-based analysis due to time limitations. The pseudocode for the algorithm is as follows:

```
while (not all 300s have completed their maintenance):
   for all periods:
      find the LOLE of each period
   end for
   evaluate the average of every 3 consecutive LOLEs and mark each average with the period of the first of the 3
   arrange the set of averages in ascending order and arrange their periods as well
   choose the period of the first element
   while (the period or one of the two that follow have already three maintenance units at it):
         choose the following period in the array
   end while
   perform maintenance of 300 at this period:
       increment the number of maintenance units at this period and at the following 2
      remove a 300 unit at this period
      recompute COT
   end perform
end while
Repeat the same for 100 MW
```