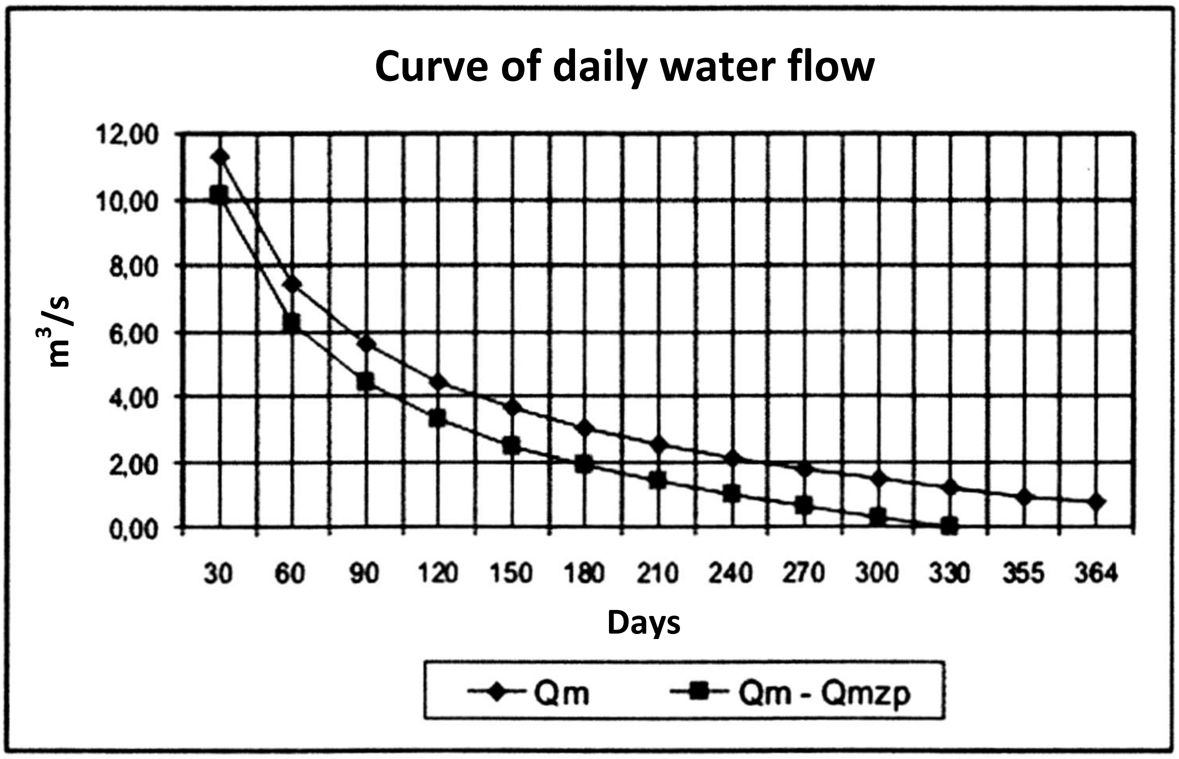
Example 1:

How is installed power of a small hydro power plant? And how would be annual energy production, if the installed power is stable for 355 days and a service outage is for 10 days (power P_s is produces by hydro power plant for 355 days). The dependence of a water flow Q to time t is plotted in the graph. The real head of water is H = 3 m, the turbine efficiency is η_T = 70 %, the efficiency of torque transfer from the turbine shaft to the generator shaft is η_p = 94 % and generator efficiency is η_g = 87 %.



Solution:

Water flow can be read from the lower curve in the graph (reactive dam overflow is taken to the account) between 90 and 120 days (common economical design of maximal turbine power):

⇨ Q = 3.9 $m^3 \cdot s^{-1}$

Installed power:

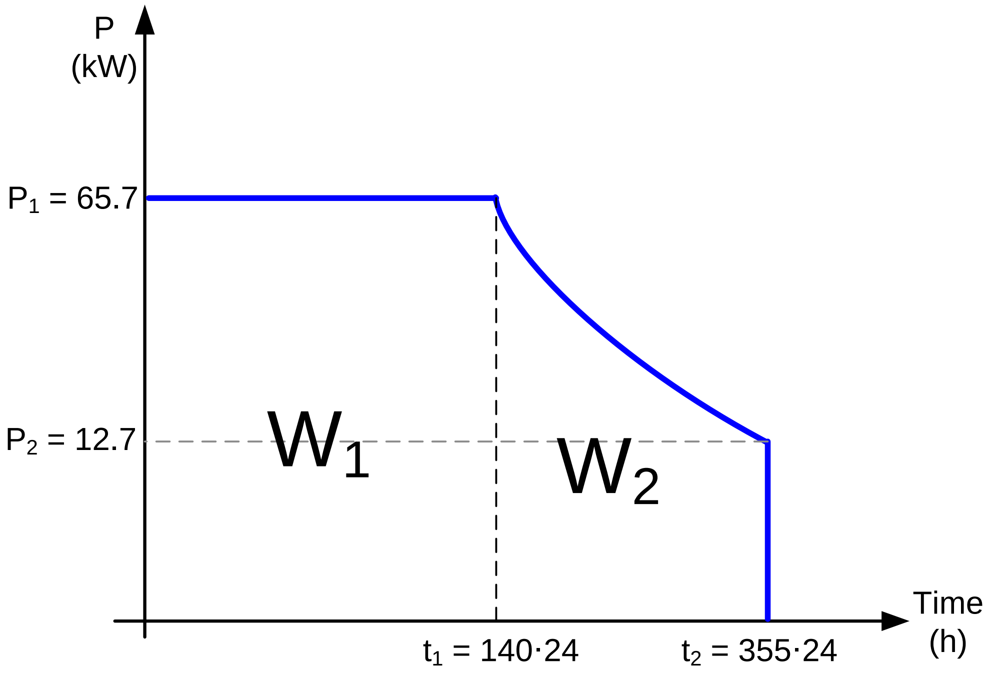
$$P_s = \rho \cdot g \cdot Q \cdot H \cdot \eta_T \cdot \eta_p \cdot \eta_g = 1000 \cdot 9.81 \cdot 3.9 \cdot 3 \cdot 0.7 \cdot 0.94 \cdot 0.87 = 65705\ W = 65.7\ kW$$

Annual energy production:

$$W = \int_0^t P dt = [65.7 \cdot t]_0^{355 \cdot 24} = 559764\ kWh = 559.76\ MWh$$

Example 2:

How is annual energy production of a small hydro power plant given by the load diagram?



Solution:

Energy production:

$$W = W1 + W2$$

$$\mathbf{W_1} = \int_0^{t_1} P_1 dt = [65.7 \cdot t]_0^{140\cdot 24} = 220752\ \mathrm{kWh} = \mathbf{220.75\ MWh}$$

$$W_2 = \int_{t_1}^{t_2} P_x dt$$

Calculation of exponential function:

$$P_x = a \cdot e^{-b\cdot t} = \begin{cases} P_1 = a \cdot e^{-b\cdot t_1} \\ P_2 = a \cdot e^{-b\cdot t_2} \end{cases}$$

$$\frac{P_1}{P_2} = e^{b(t_2 - t_1)} \rightarrow b = \frac{\ln(\frac{P_1}{P_2})}{t_2 - t_1}$$

$$a = \frac{P_1}{e^{-b\cdot t_1}}$$

$$\frac{65.7}{12.7} = \mathrm{e}^{\mathrm{b}(355\cdot 24 - 140\cdot 24)} \rightarrow \mathrm{b} = \frac{\ln(5.02)}{215 \cdot 24} = 3.185 \cdot 10^{-4}\ h^{-1}$$

$$\mathrm{a} = \frac{65.7}{\mathrm{e}^{-3.185\cdot 10^{-4}\cdot 140\cdot 24}} = 191.57\ \mathrm{kW}$$

$$\mathrm{P}_x = 191.57 \cdot \mathrm{e}^{-3.185\cdot 10^{-4}\cdot \mathrm{t}}\ kW$$

$$\mathrm{W}_2 = \int_{\mathrm{t}_1}^{\mathrm{t}_2} \mathrm{P}_x \cdot \mathrm{dt} = \int_{\mathrm{t}_1}^{\mathrm{t}_2} \mathrm{a} \cdot \mathrm{e}^{-\mathrm{b}\cdot \mathrm{t}} \cdot \mathrm{dt} = \frac{\mathrm{a}}{-\mathrm{b}} \cdot \left[\mathrm{e}^{-\mathrm{b}\cdot \mathrm{t}}\right]_{t_1}^{t_2}$$

$$\boldsymbol{W_2} = \frac{191.57}{-3.185 \cdot 10^{-4}} \cdot \left[\mathrm{e}^{-3.185\cdot 10^{-4}\cdot \mathrm{t}}\right]_{140\cdot 24}^{355\cdot 24} = 166402.6\ kWh = \mathbf{166.4\ MWh}$$

Total annual energy production:

$$\mathbf{W} = \mathrm{W}_1 + \mathrm{W}_2 = 220.75 + 166.4 = \mathbf{387.15\ MWh}$$