# Physics based hydropower optimization

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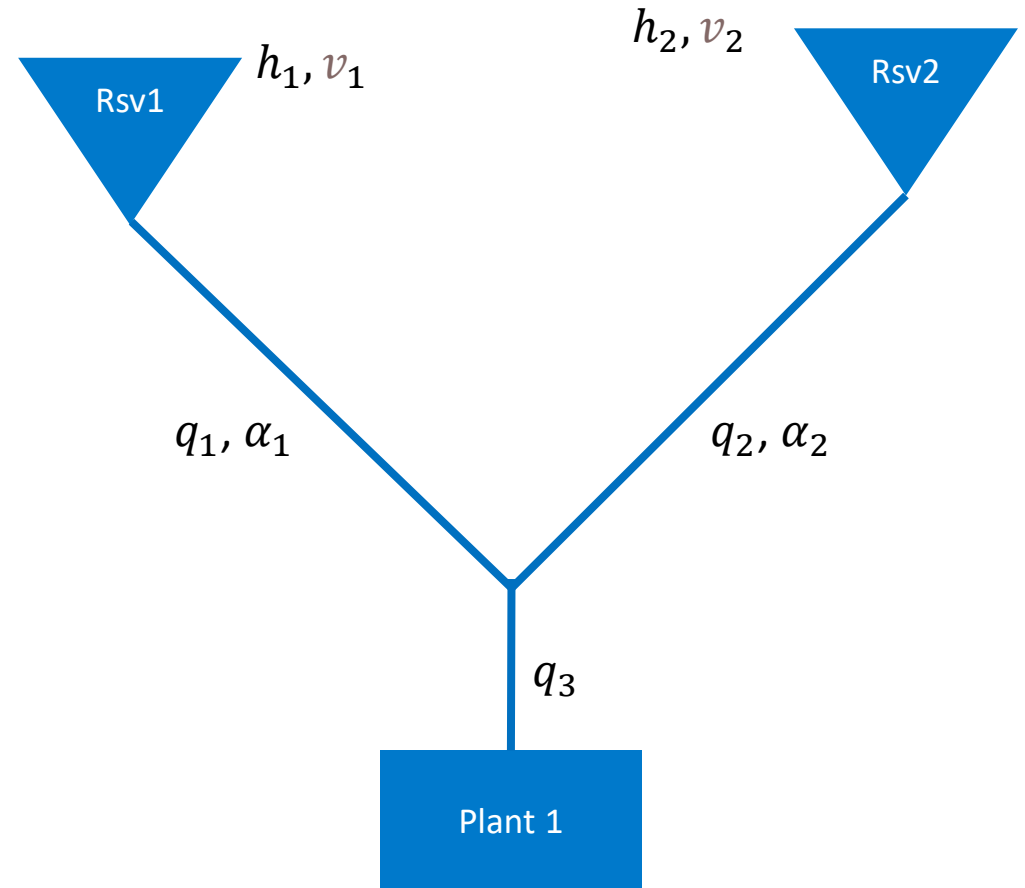
User Meeting – 17.11.2021

# Basic pressurized system

- Amount of water going in and out of junction must be the same
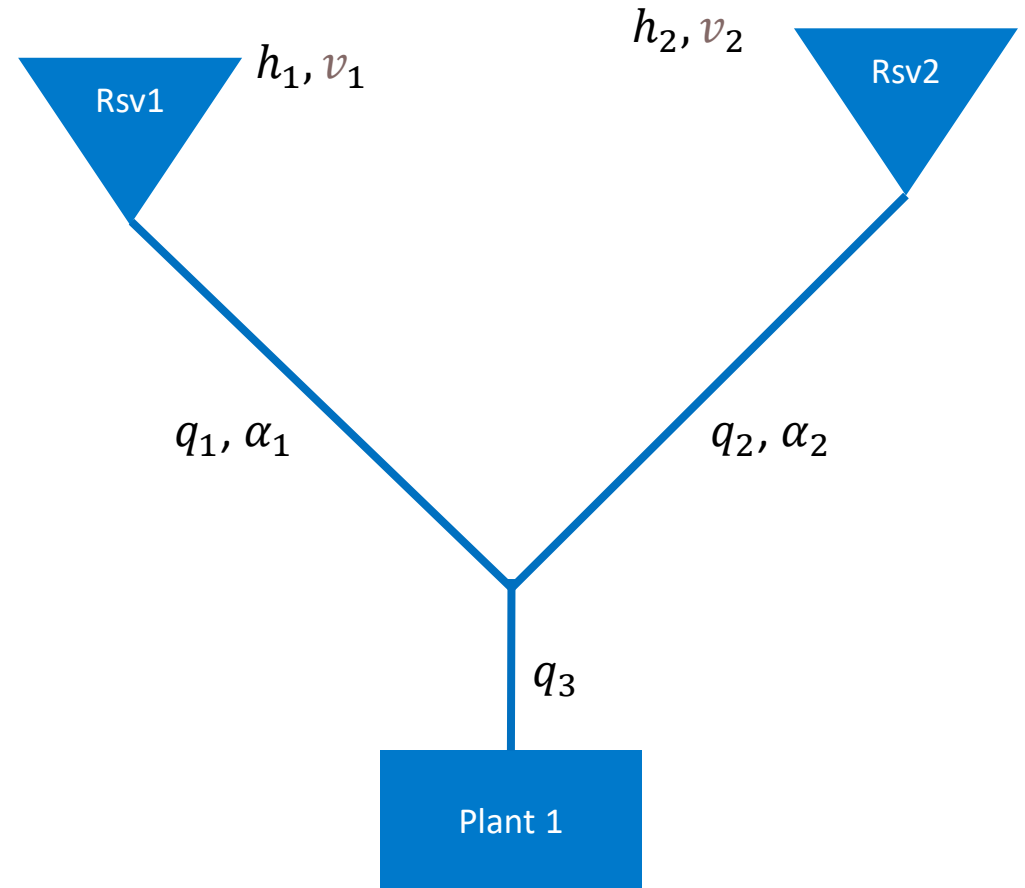
$$q_1 + q_2 = q_3$$

- Pressure must be the same at the end of both tunnels meeting in the junction

$$h_1 - \alpha_1 q_1 |q_1| = h_2 - \alpha_2 q_2 |q_2|$$



$h_2, v_2$

$h_1, v_1$

Rsv1

Rsv2

$q_1, \alpha_1$

$q_2, \alpha_2$

$q_3$

Plant 1

# Basic pressurized system

- Amount of water going in and out of junction must be the same

$$q_1 + q_2 = q_3$$

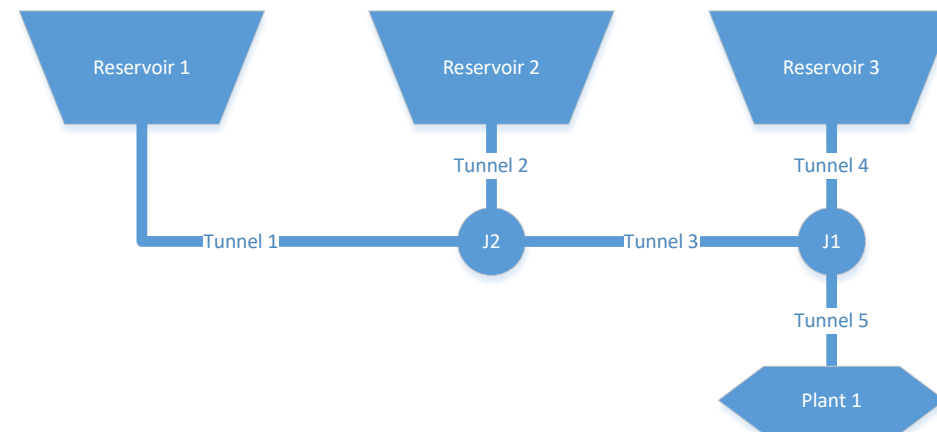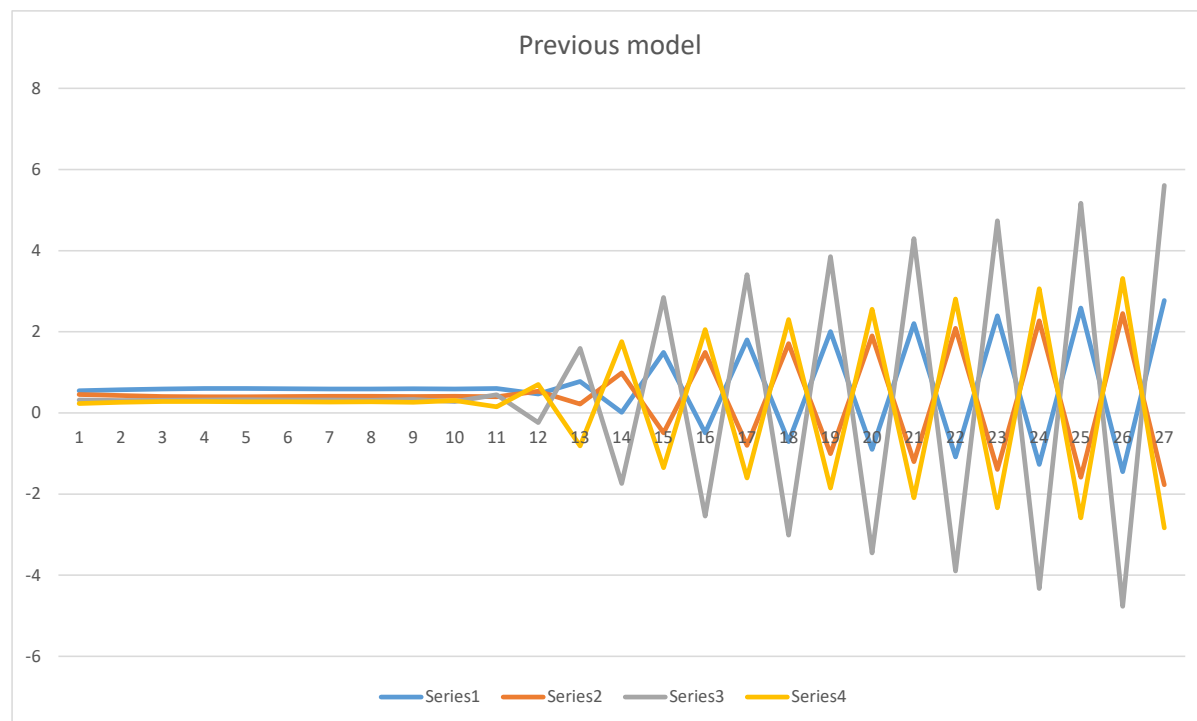- Pressure must be the same at the end of both tunnels meeting in the junction

$$h_1 - \alpha_1 q_1 |q_1| = h_2 - \alpha_2 q_2 |q_2|$$

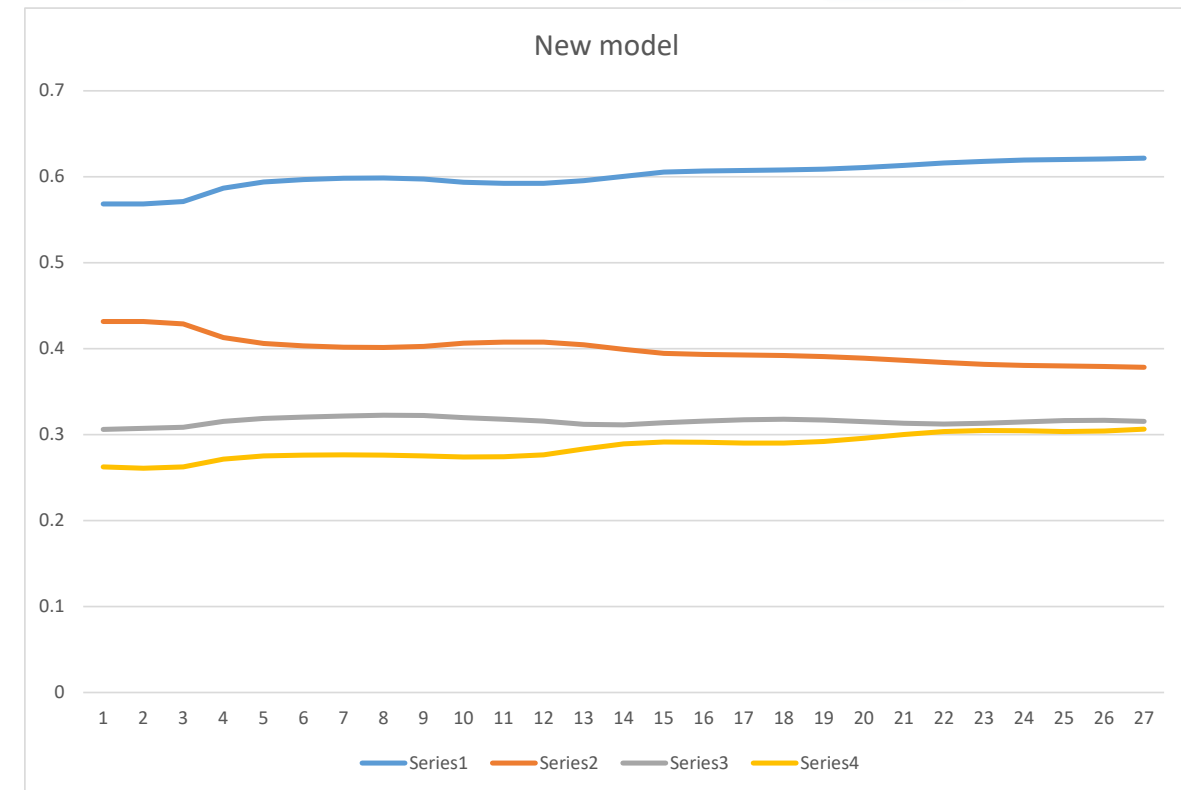- Add first-order correction for dynamic head variation in reservoirs
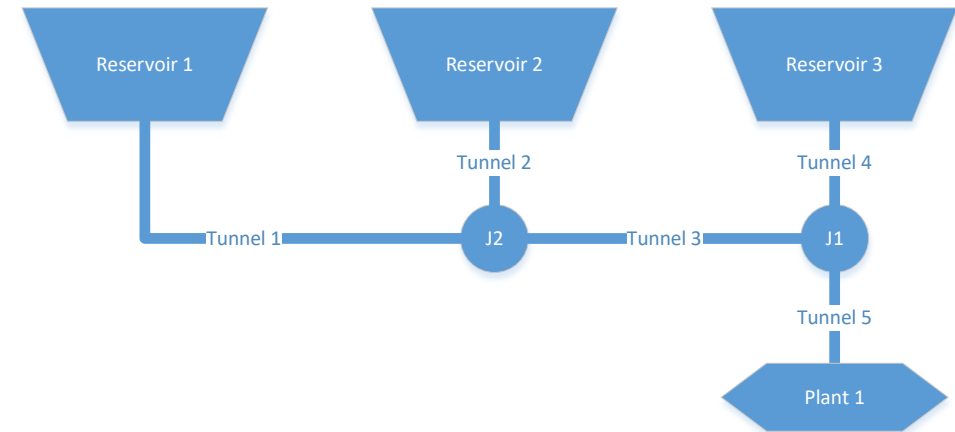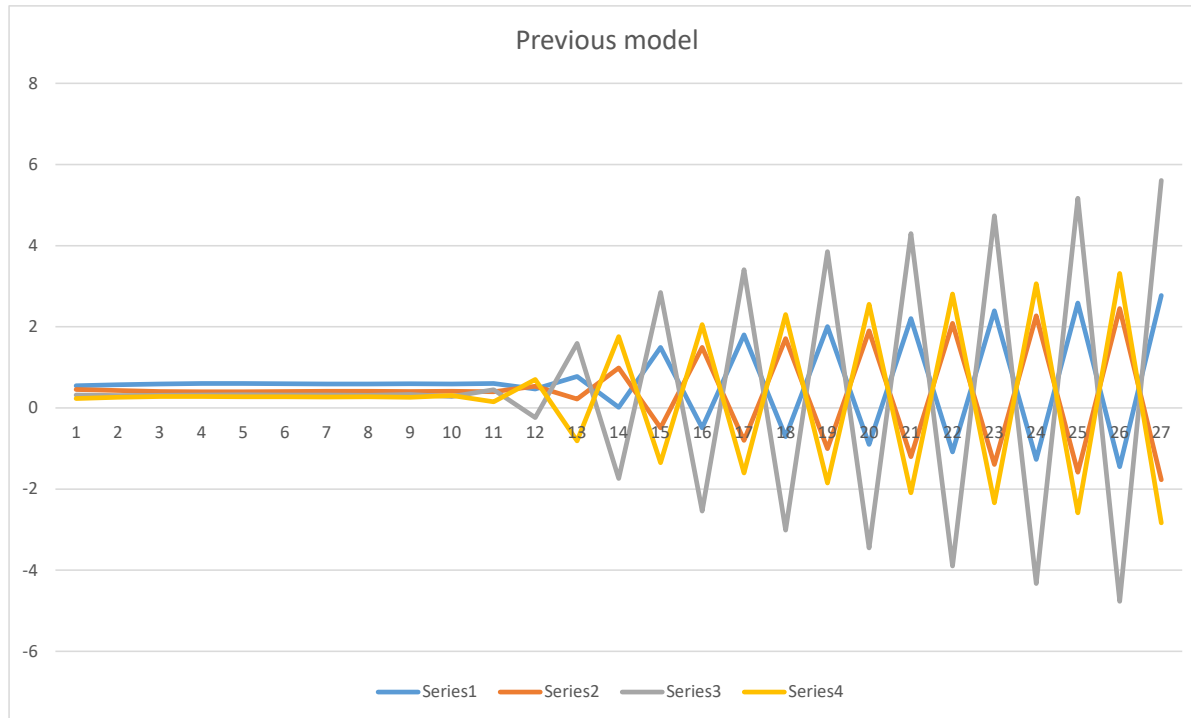
$$h_1 - \frac{\partial h_1}{\partial v_1} q_1 - \alpha_1 q_1 |q_1| = h_2 - \frac{\partial h_2}{\partial v_2} q_2 - \alpha_2 q_2 |q_2|$$

$h_2, v_2$

Rsv2

$h_1, v_1$

Rsv1

$q_1, \alpha_1$

$q_2, \alpha_2$

$q_3$

Plant 1

# Test system with small reservoirs



Previous model

# Test system with small reservoirs



Previous model

New model

# Basic pressurized system

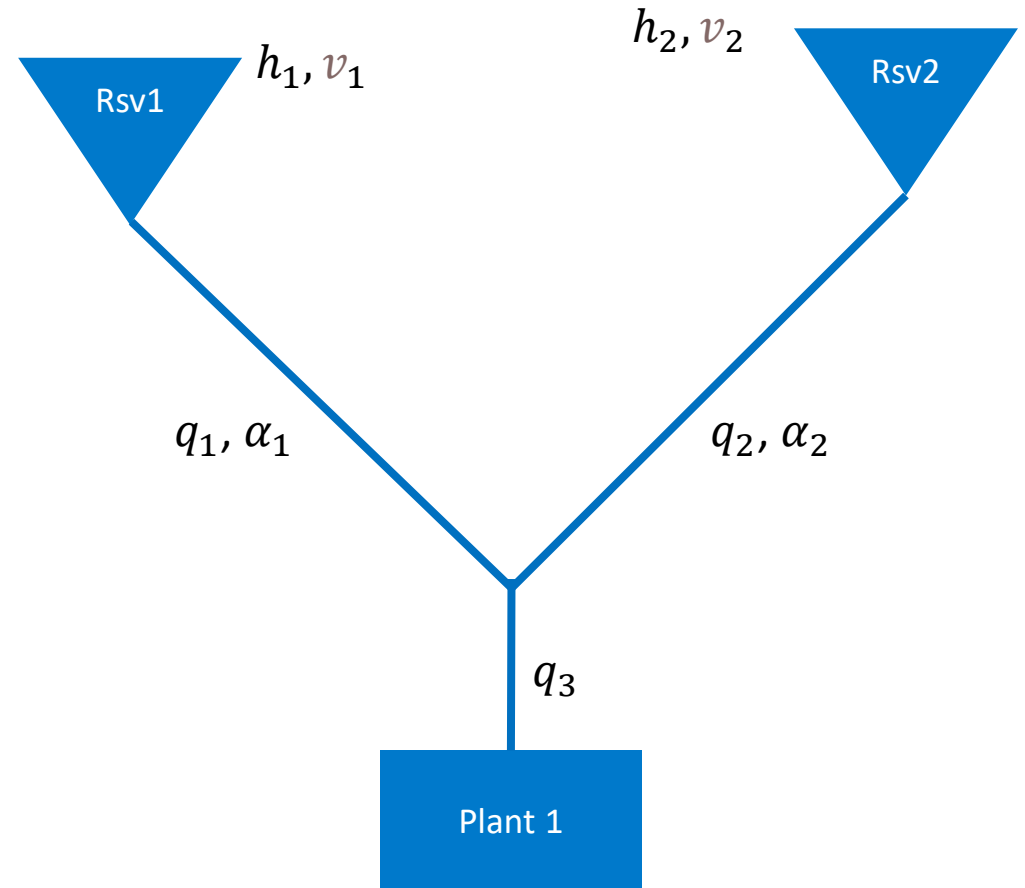- Amount of water going in and out of junction must be the same

$$q_1 + q_2 = q_3$$

- Pressure must be the same at the end of both tunnels meeting in the junction

$$h_1 - \alpha_1 q_1 |q_1| = h_2 - \alpha_2 q_2 |q_2|$$

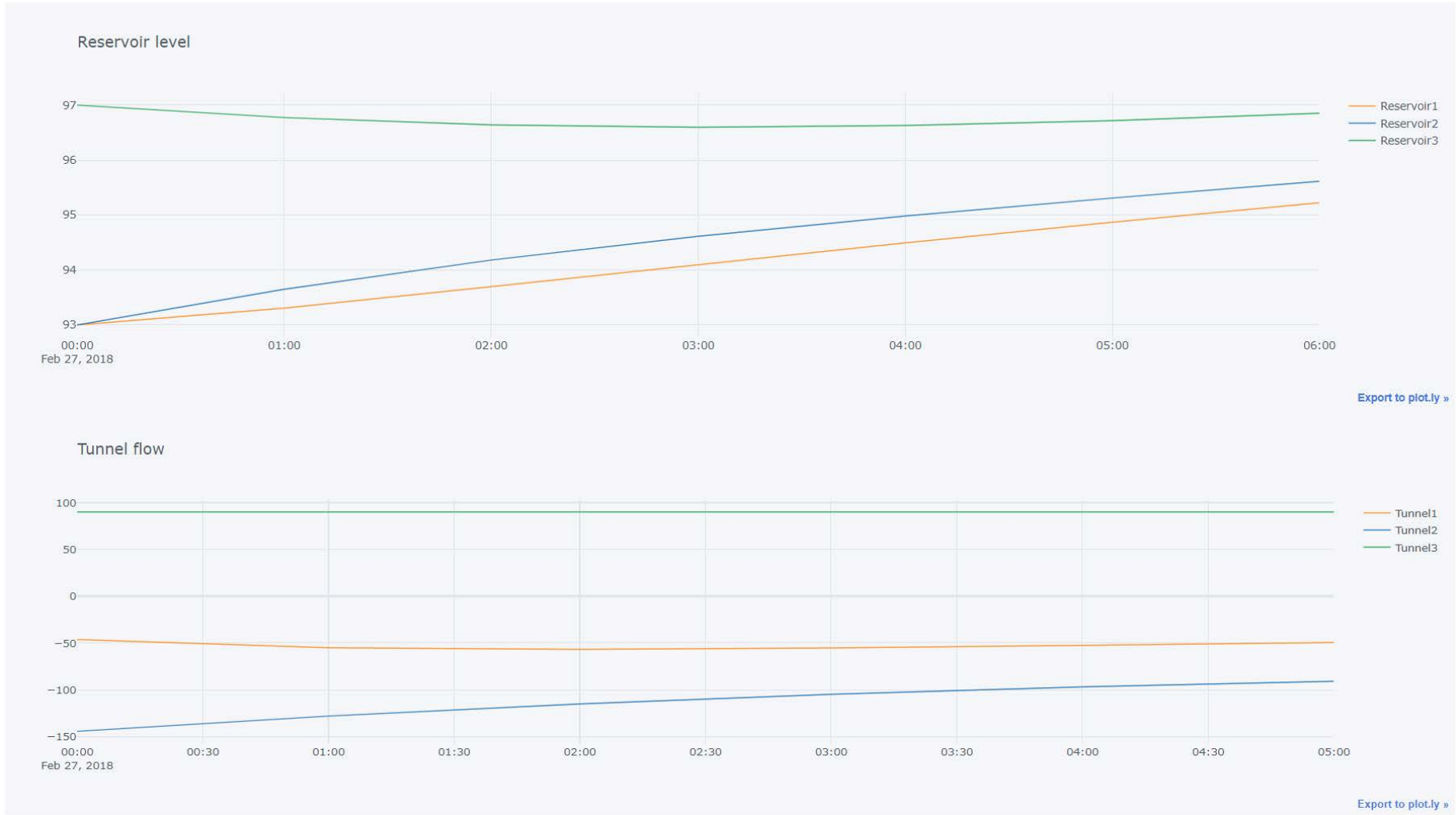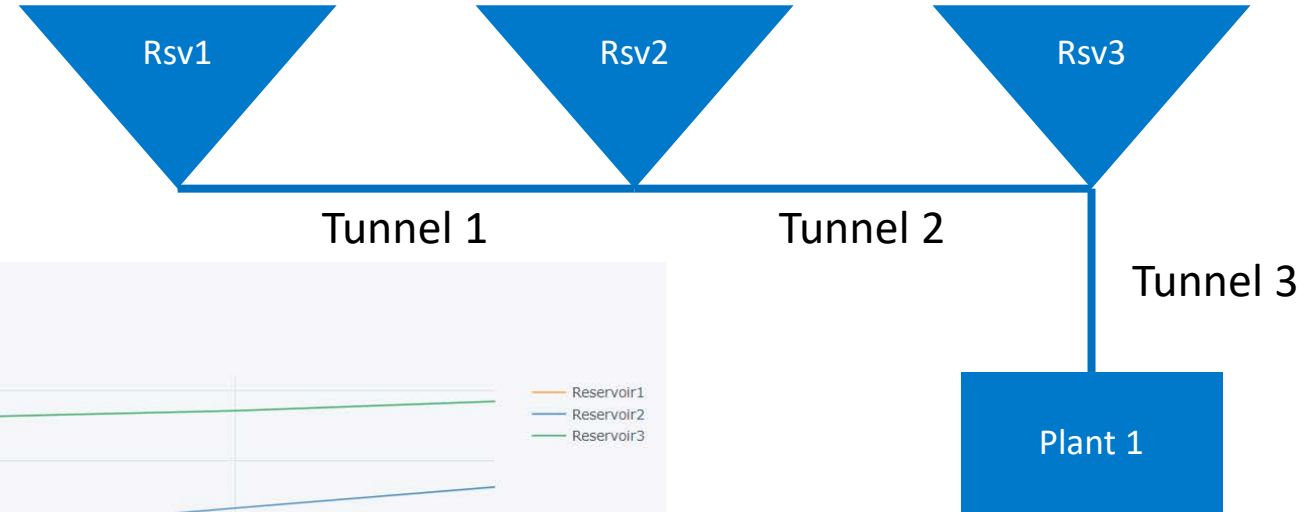- Add first-order correction for dynamic head variation in reservoirs

$$h_1 - \frac{\partial h_1}{\partial v_1} q_1 - \alpha_1 q_1 |q_1| = h_2 - \frac{\partial h_2}{\partial v_2} q_2 - \alpha_2 q_2 |q_2|$$

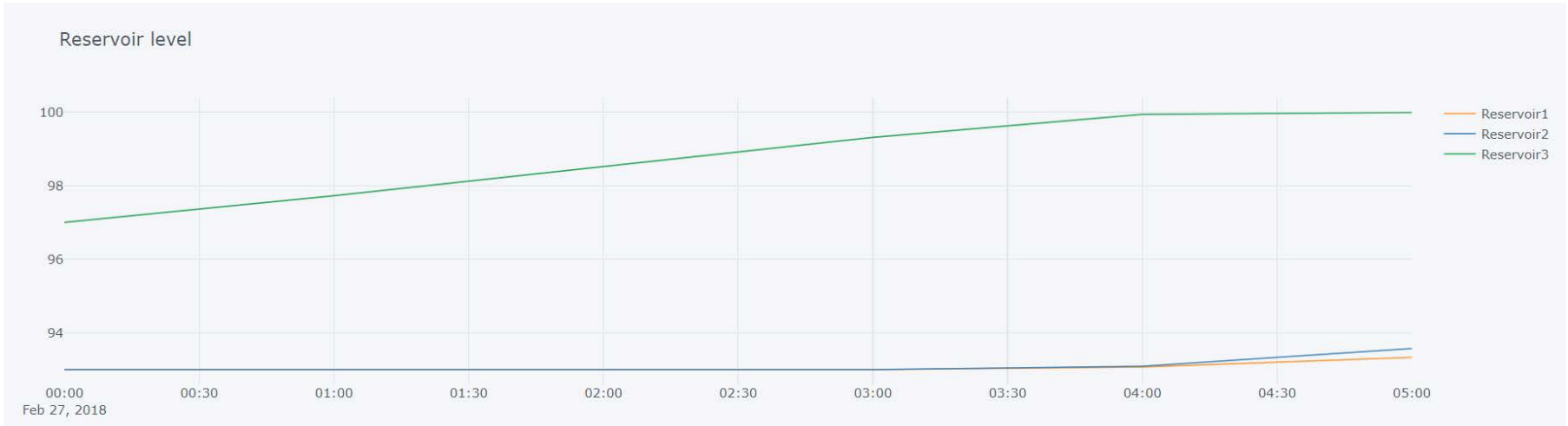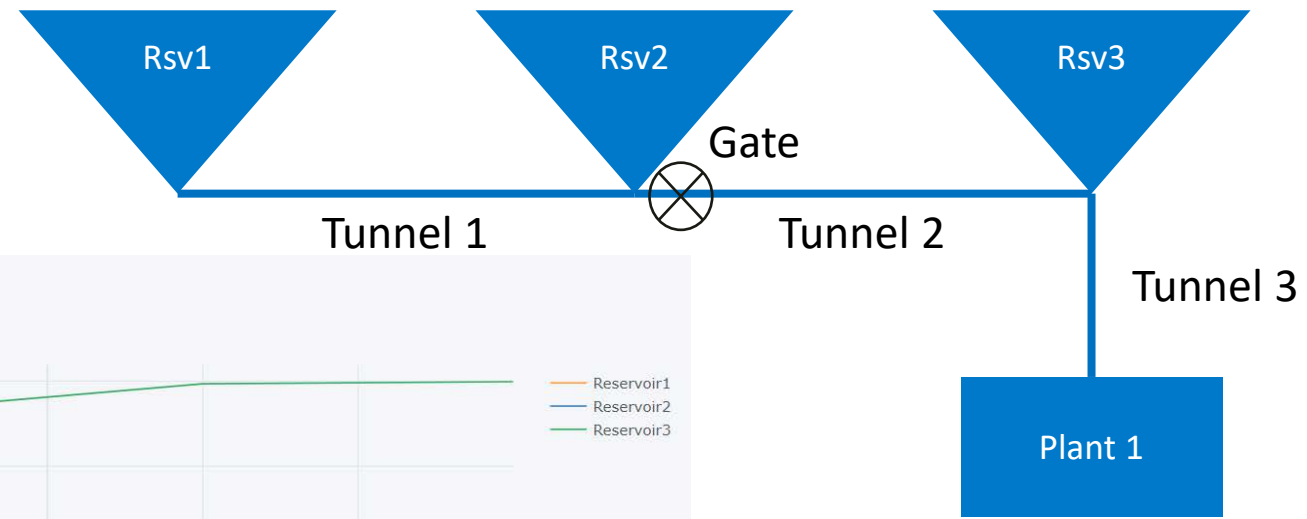# Optimization of tunnel gates
# Case 1)
# No gate

Rsv1    Rsv2    Rsv3

Tunnel 1    Tunnel 2

Tunnel 3

Plant 1

Reference = 0

# Optimization of tunnel gates
# Case 2)
# Continuous gate



Rsv1     Rsv2     Rsv3

Gate

Tunnel 1     Tunnel 2

Tunnel 3

Plant 1

**Reservoir level**

Reservoir1
Reservoir2
Reservoir3

**Gate opening**

Tunnel1
Tunnel2
Tunnel3

Export to plot.ly »

Increased objective by 3.7%
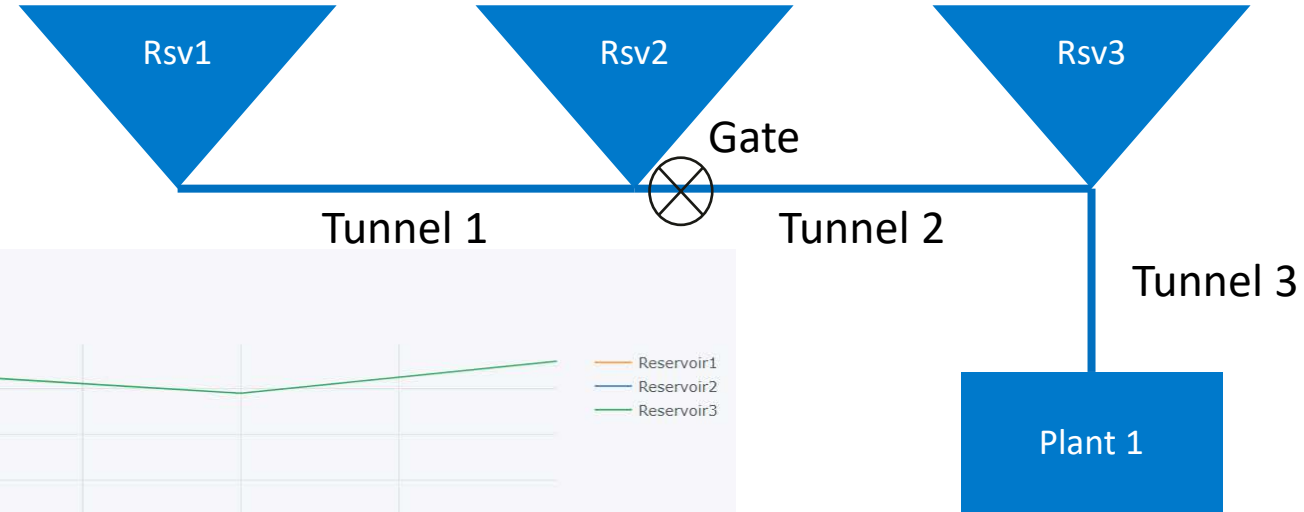
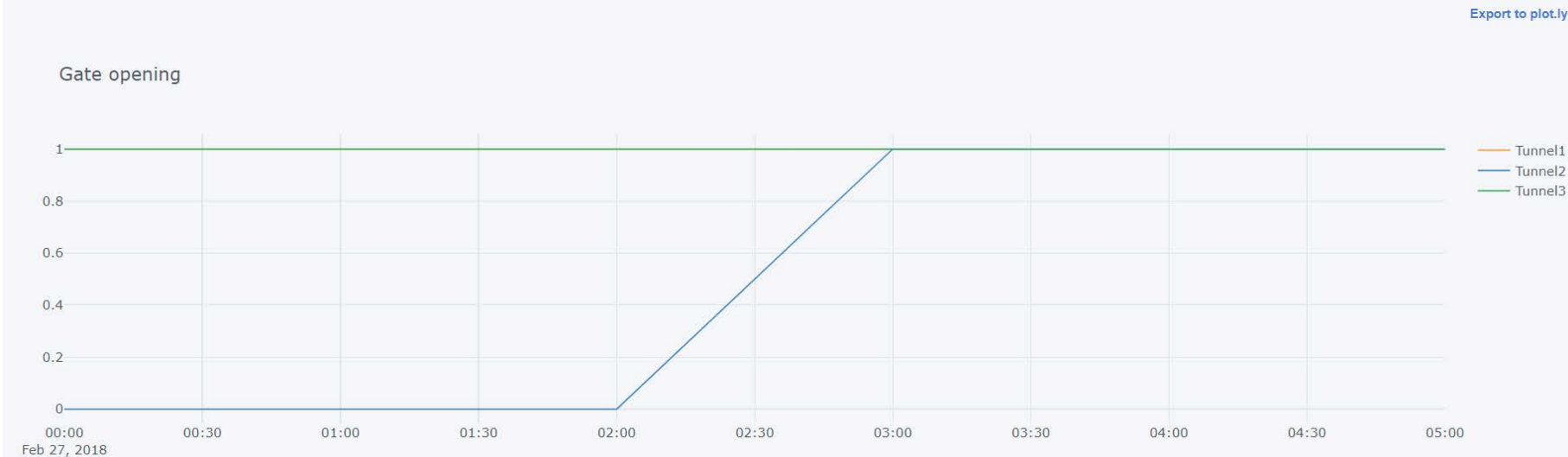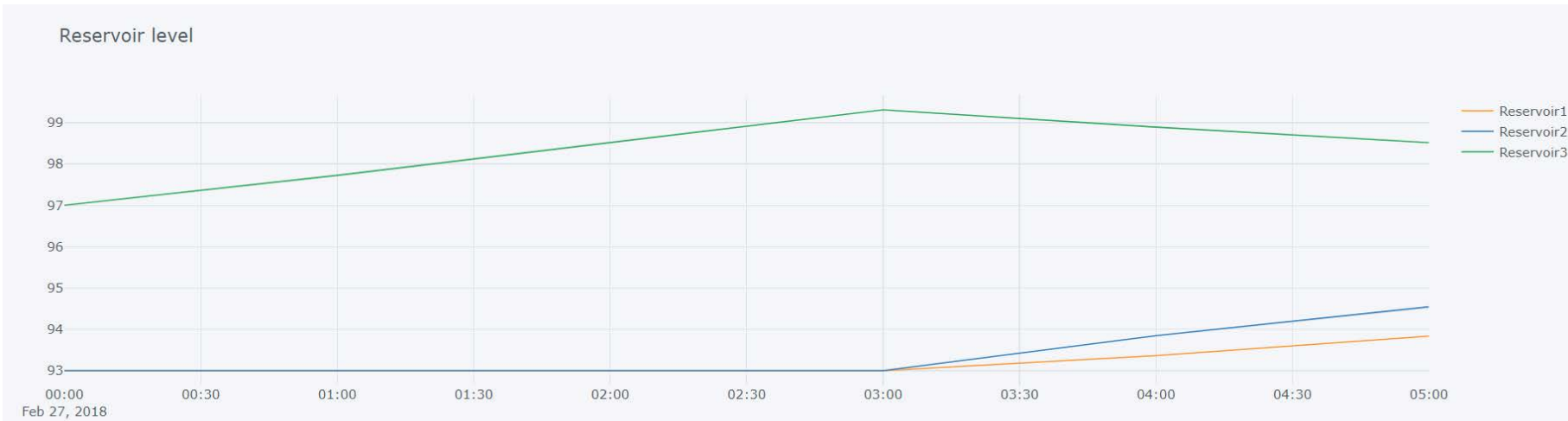# Optimization of tunnel gates
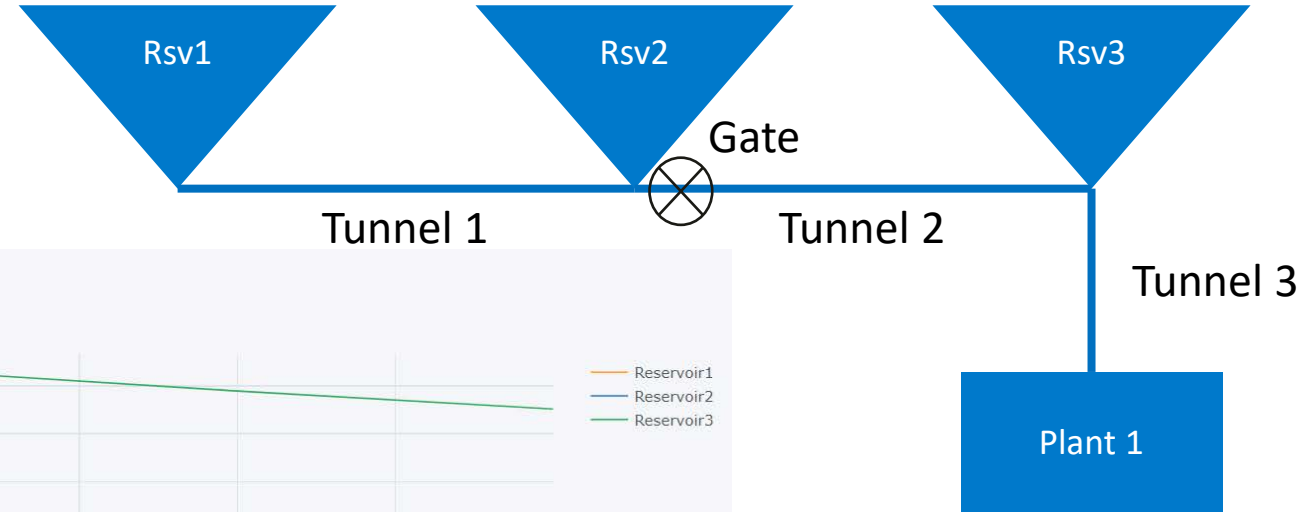# Case 3)
# Binary gate
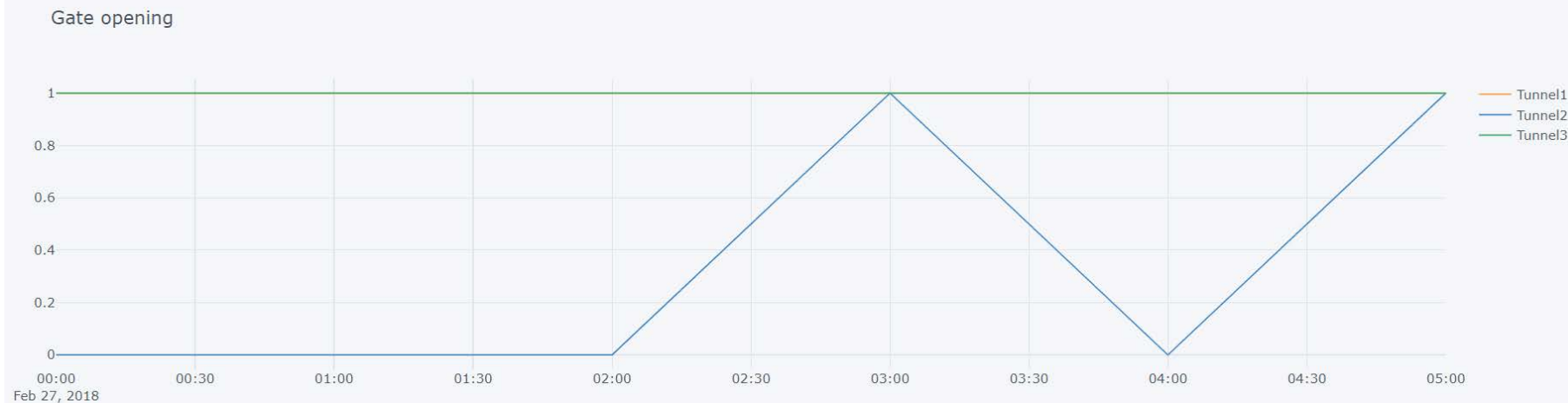


Increased objective by 3.1%

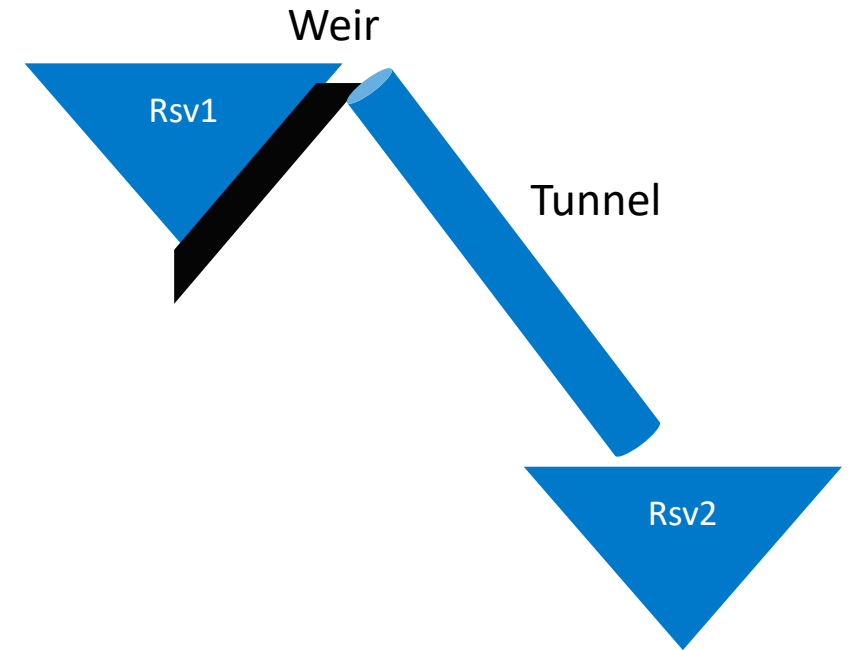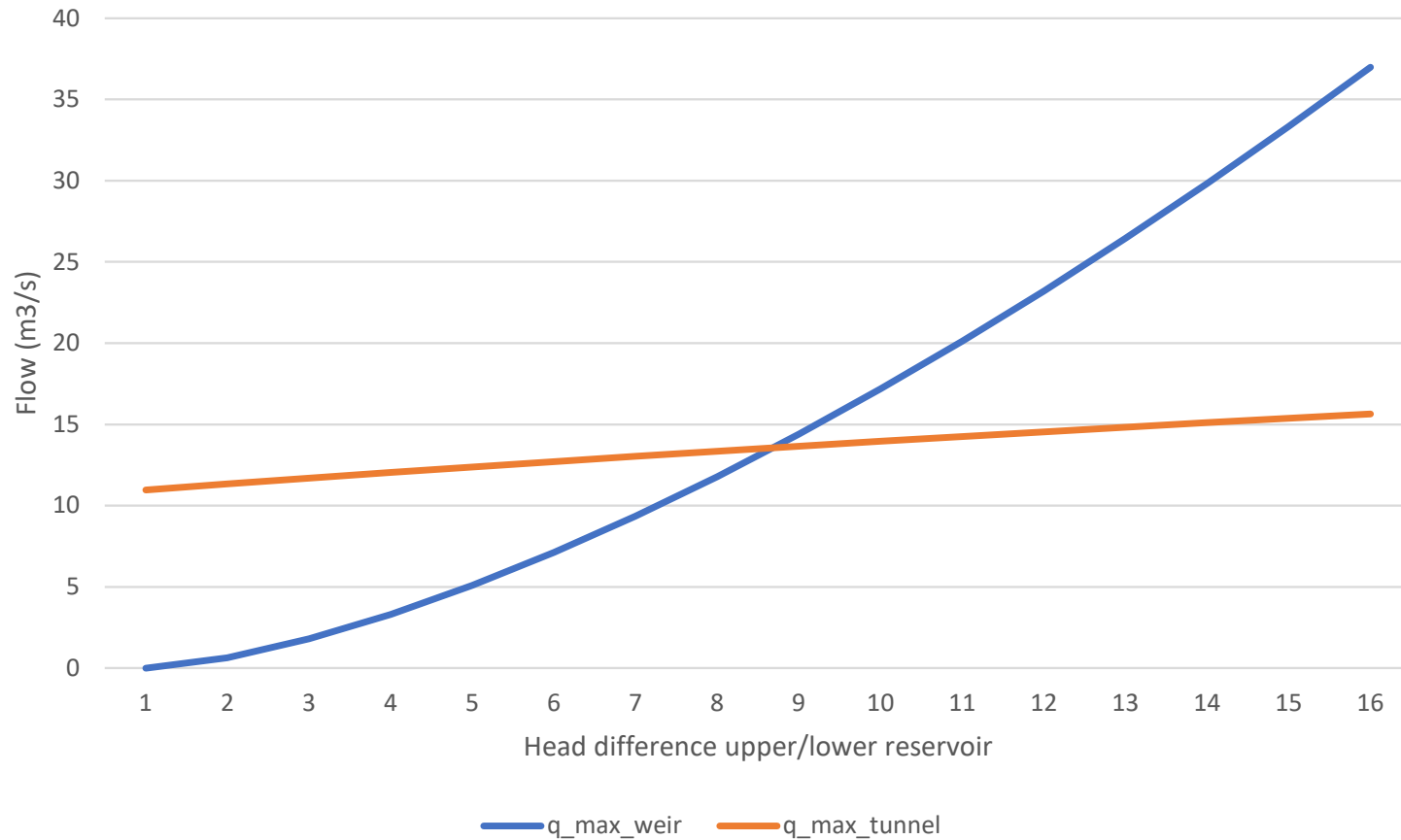# Optimization of tunnel gates
# Case 4)
# Manual gate



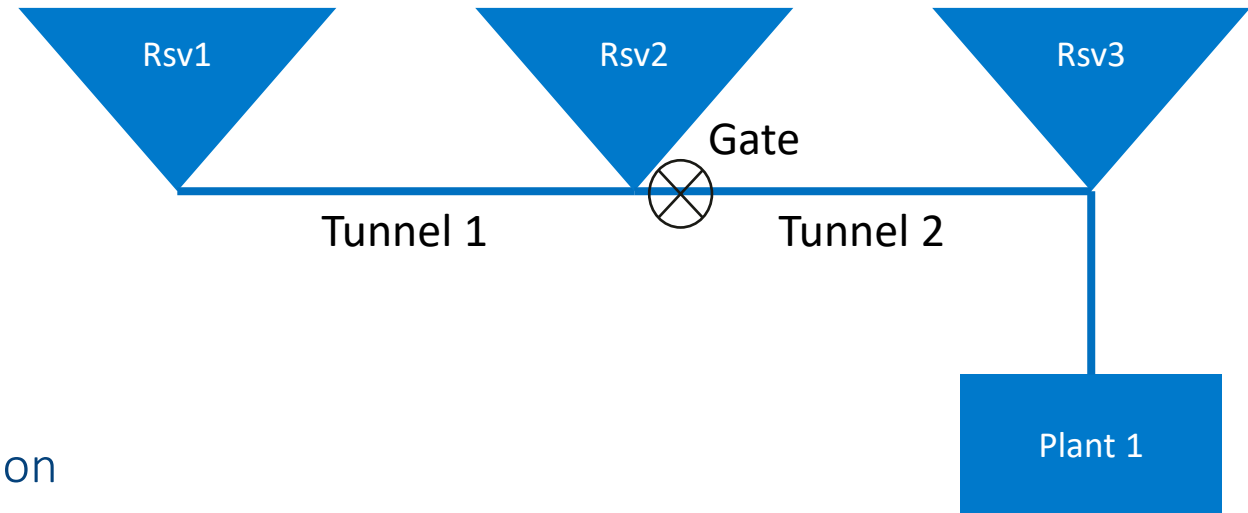Increased objective by 2.6%

# Combined physics – weir and tunnel

# Computational complexity

- ## Small case
  - 6 pressurized objects
  - 6 x 6 => 36 coefficients per state
  - 2 states => 72 coefficients per timestep
  - 200 timesteps => 14400 coefficients per iteration

- ## Large case
  - 25 pressurized objects
  - 25 x 25 => 625 coefficients per state
  - 4 states => 2500 coefficients per timestep
  - 200 timesteps => 500000 coefficients per iteration

Rsv1    Rsv2    Rsv3

Gate

Tunnel 1    Tunnel 2

Plant 1

Teknologi for et
bedre samfunn