Modeling an Integrated Energy System (IES) in OpenModelica to utilize the output of a nuclear reactor for producing energy and powering a desalination plant

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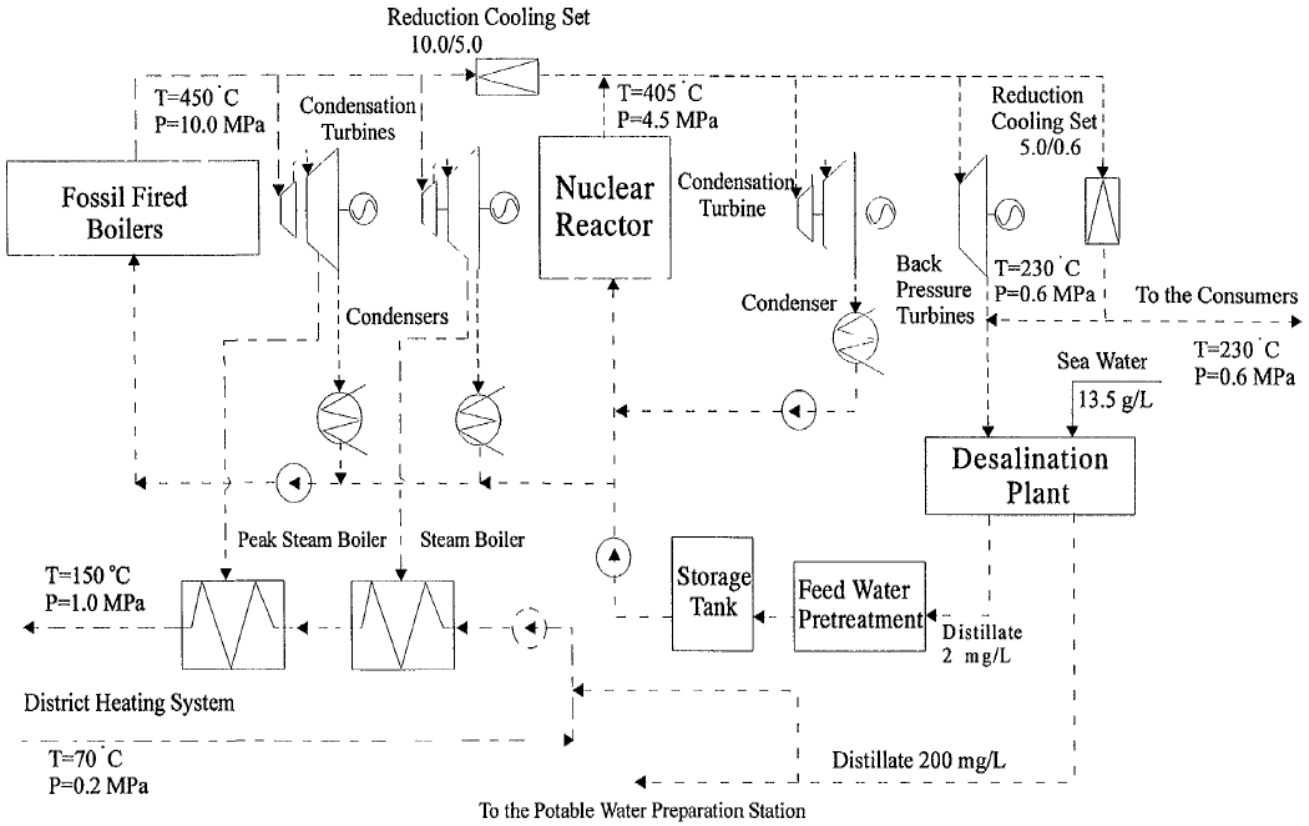
Outline

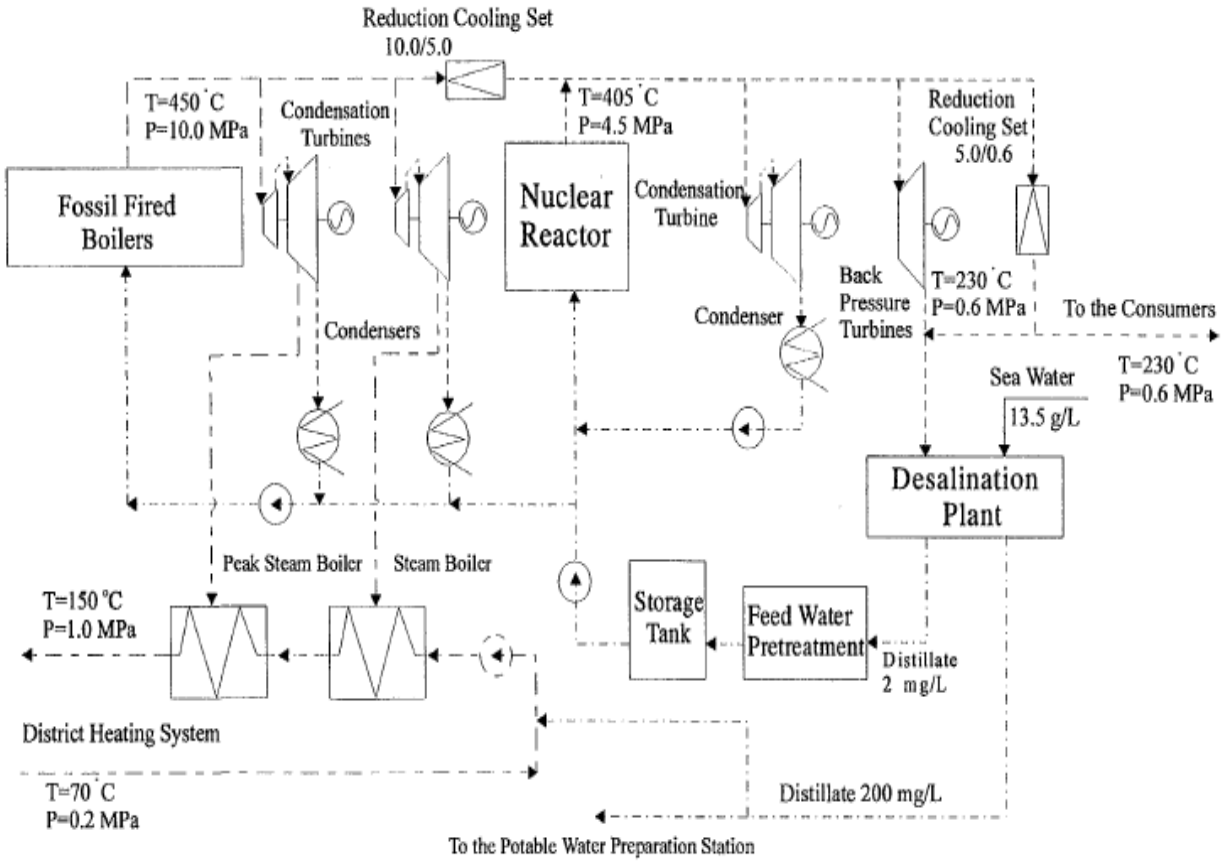
- Motivation for the work
- Modeling an Integrated Energy System
- Industrial Multi Effect Distillation (MED) Desalination Plant
- Controller System

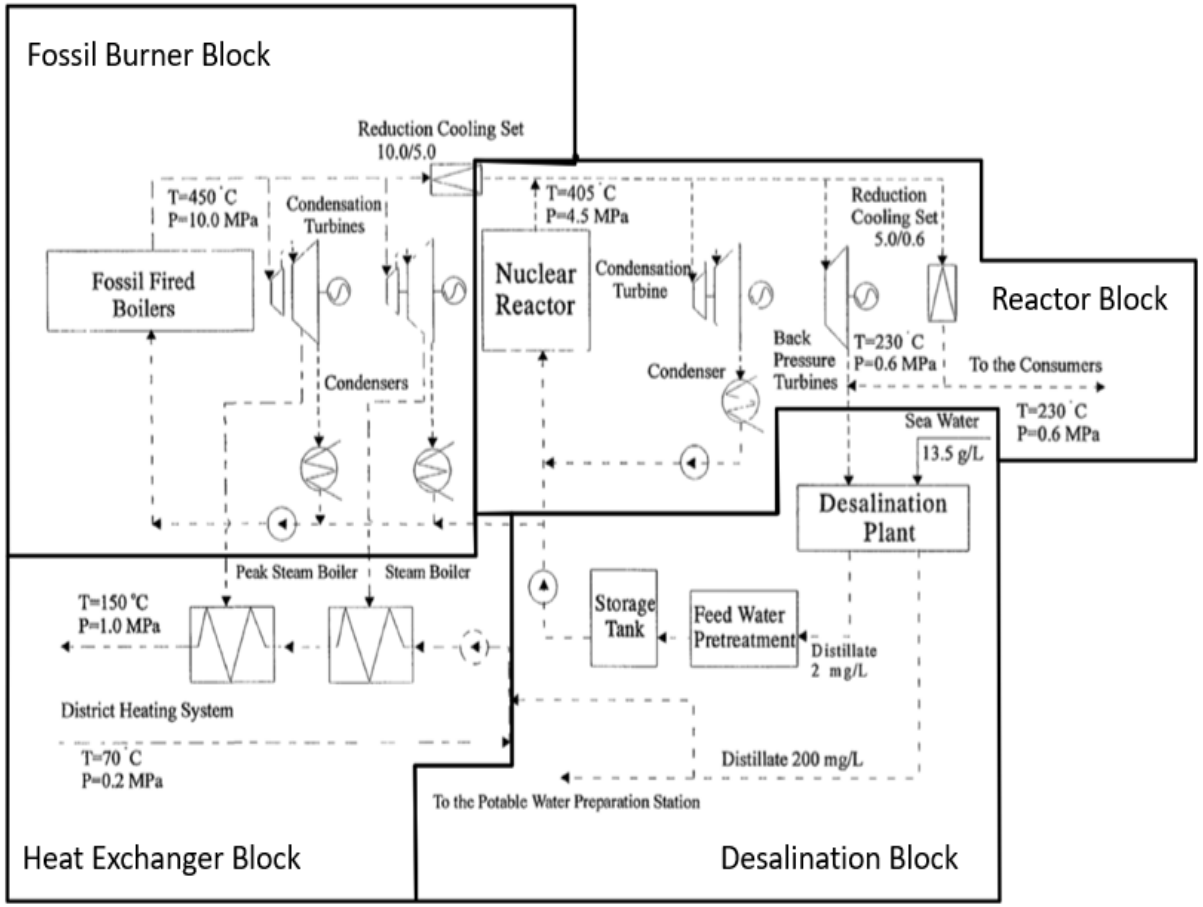
Motivation (Aktau plant complex in Kazakhstan)



- To model the thermal manifold using OpenModelica
- Main components of thermal Manifold:
  - Fossil Burner Block
  - Desalination Block
  - Reactor Block
  - Heat Exchanger Block

Motivation (Aktau plant complex in Kazakhstan)





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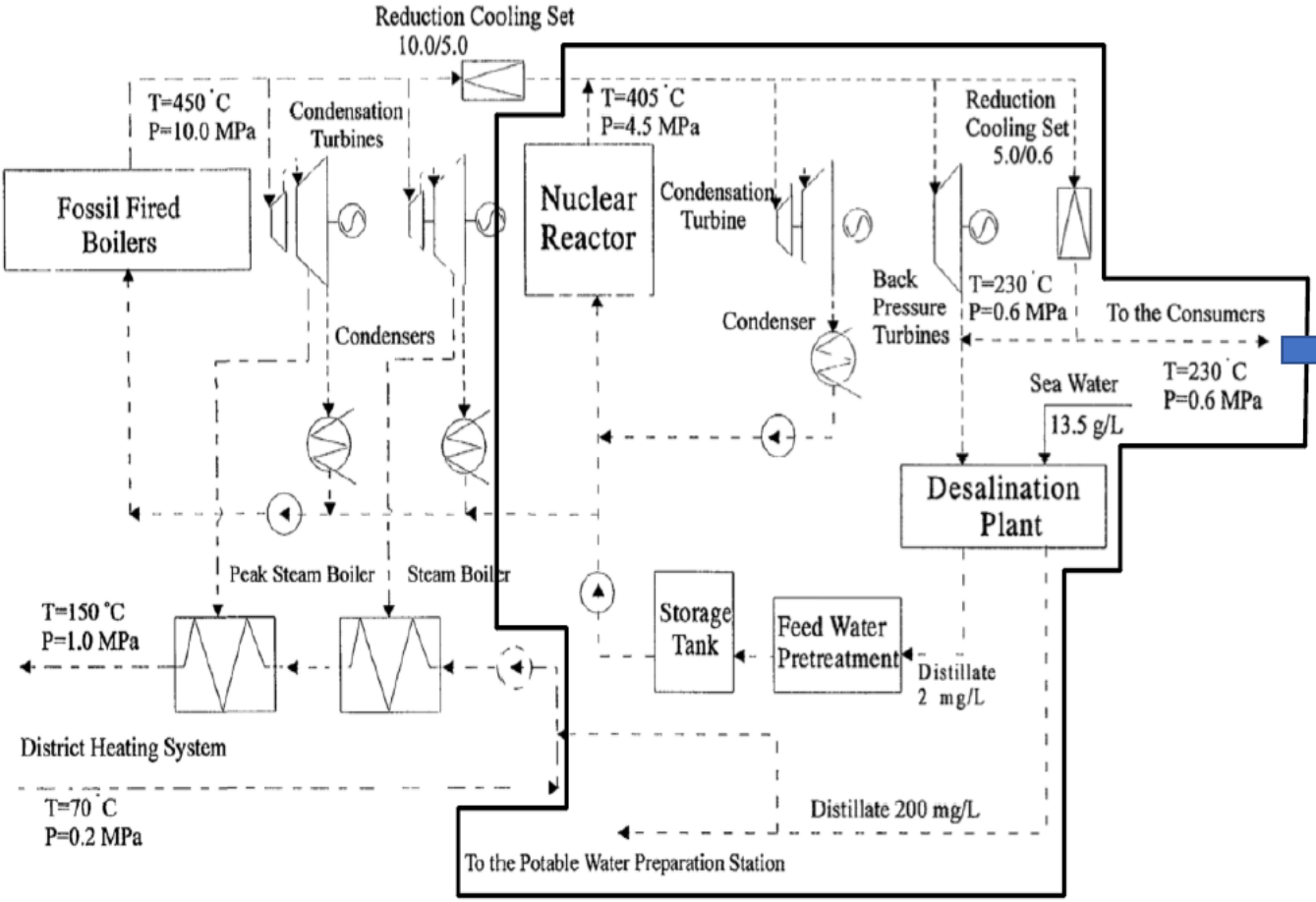
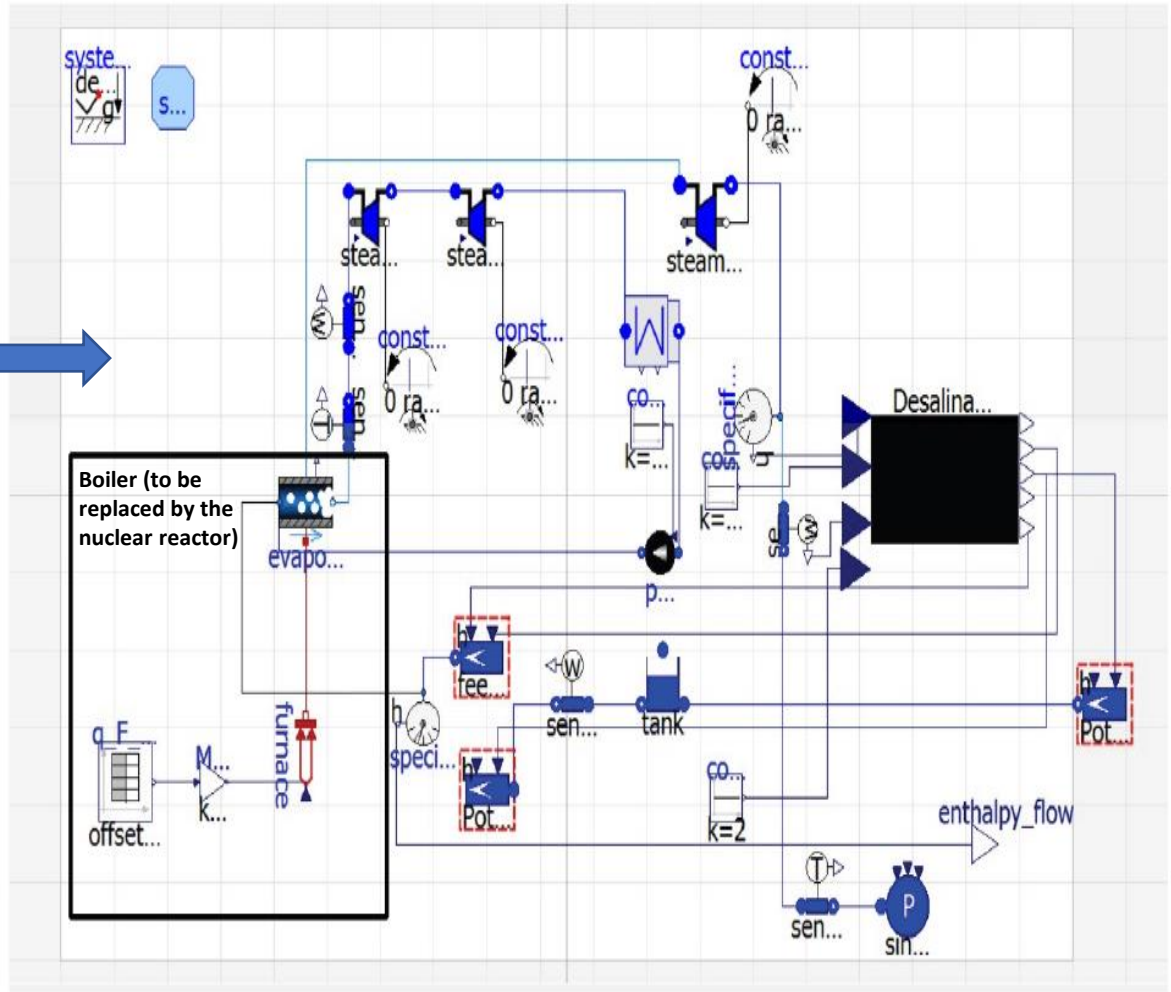
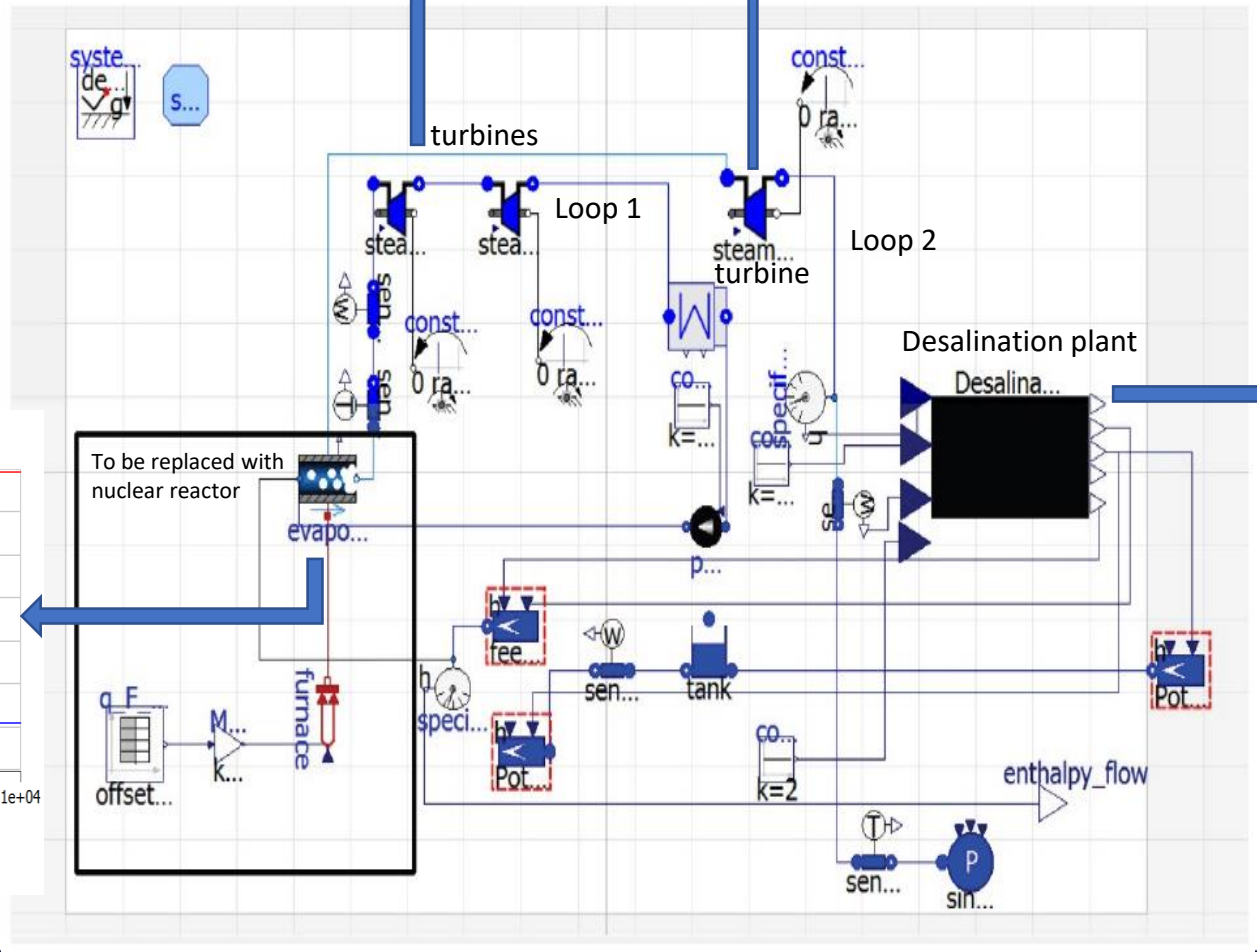
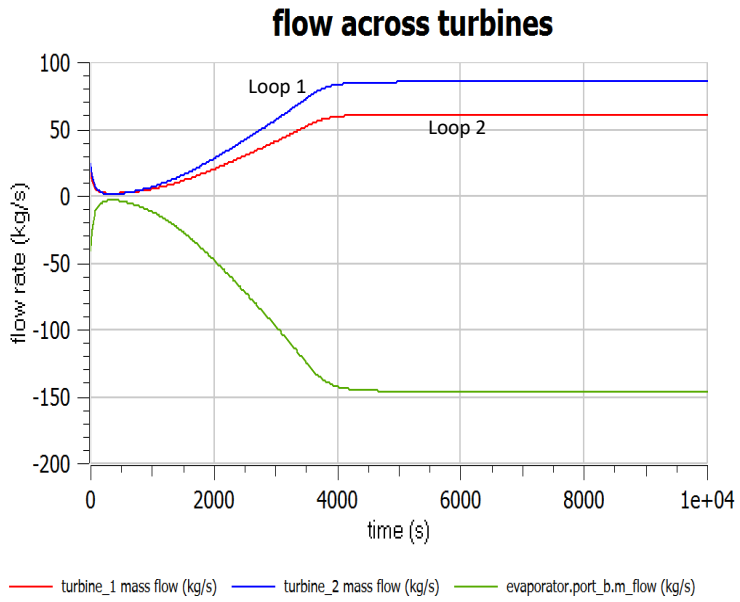
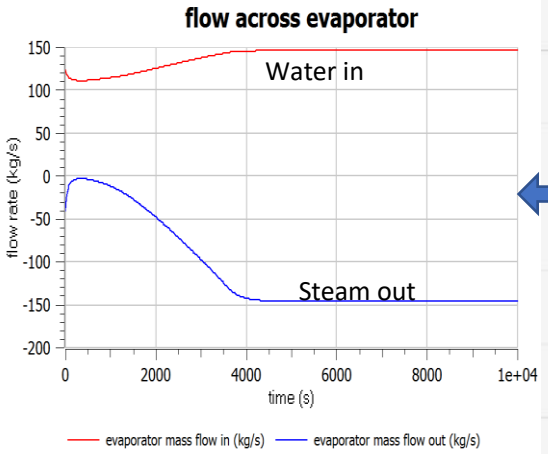


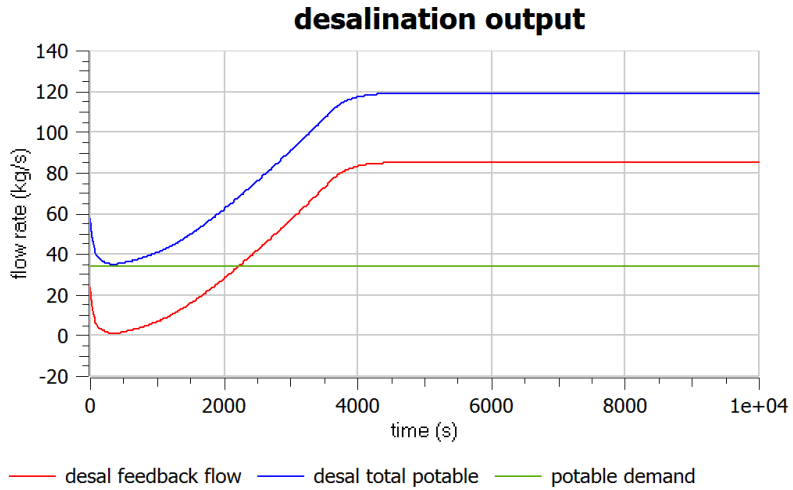


Integrated Energy System (with the primary desalination plant)

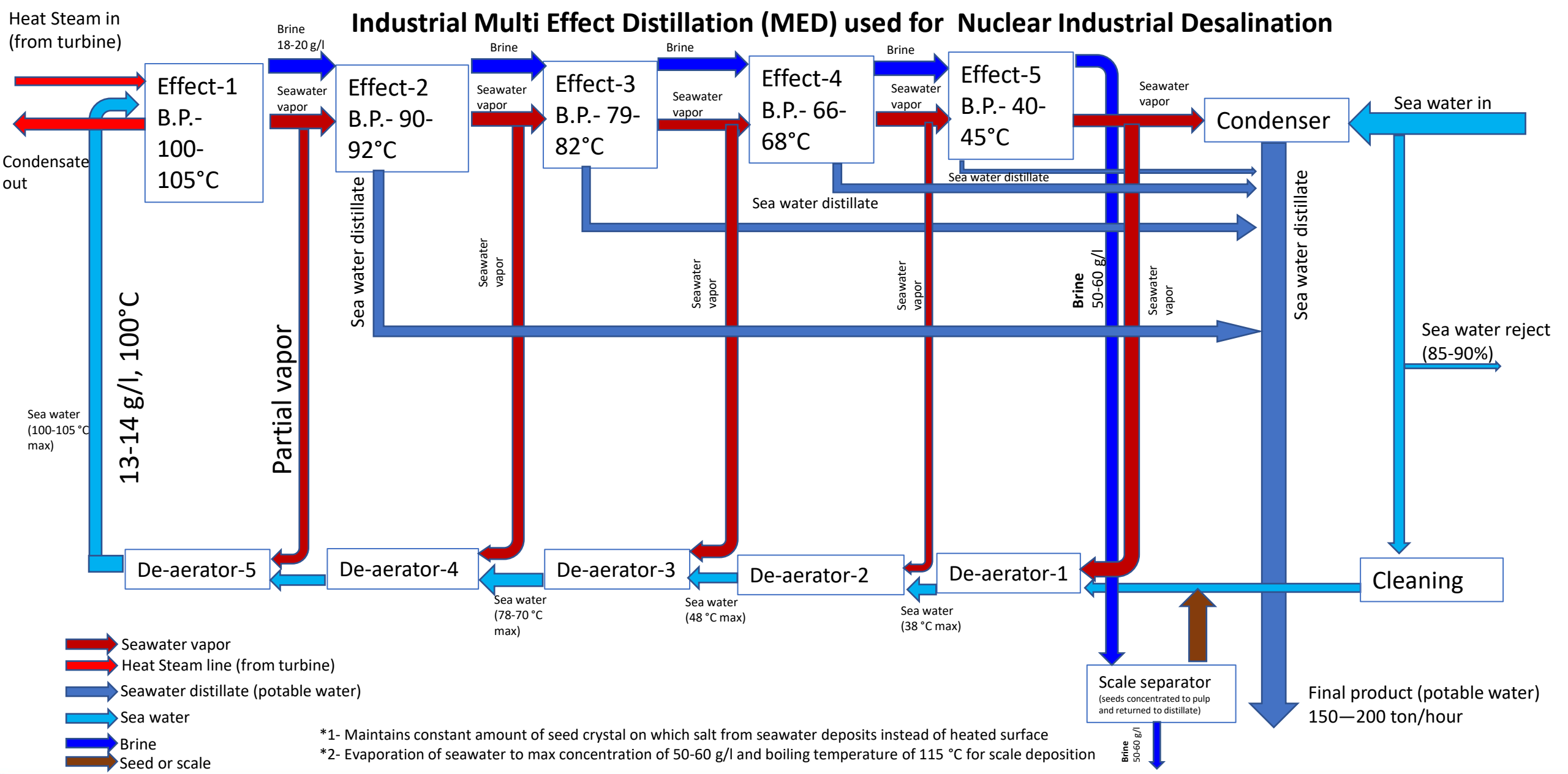








Industrial Multi Effect Distillation (MED) used for Nuclear Industrial Desalination

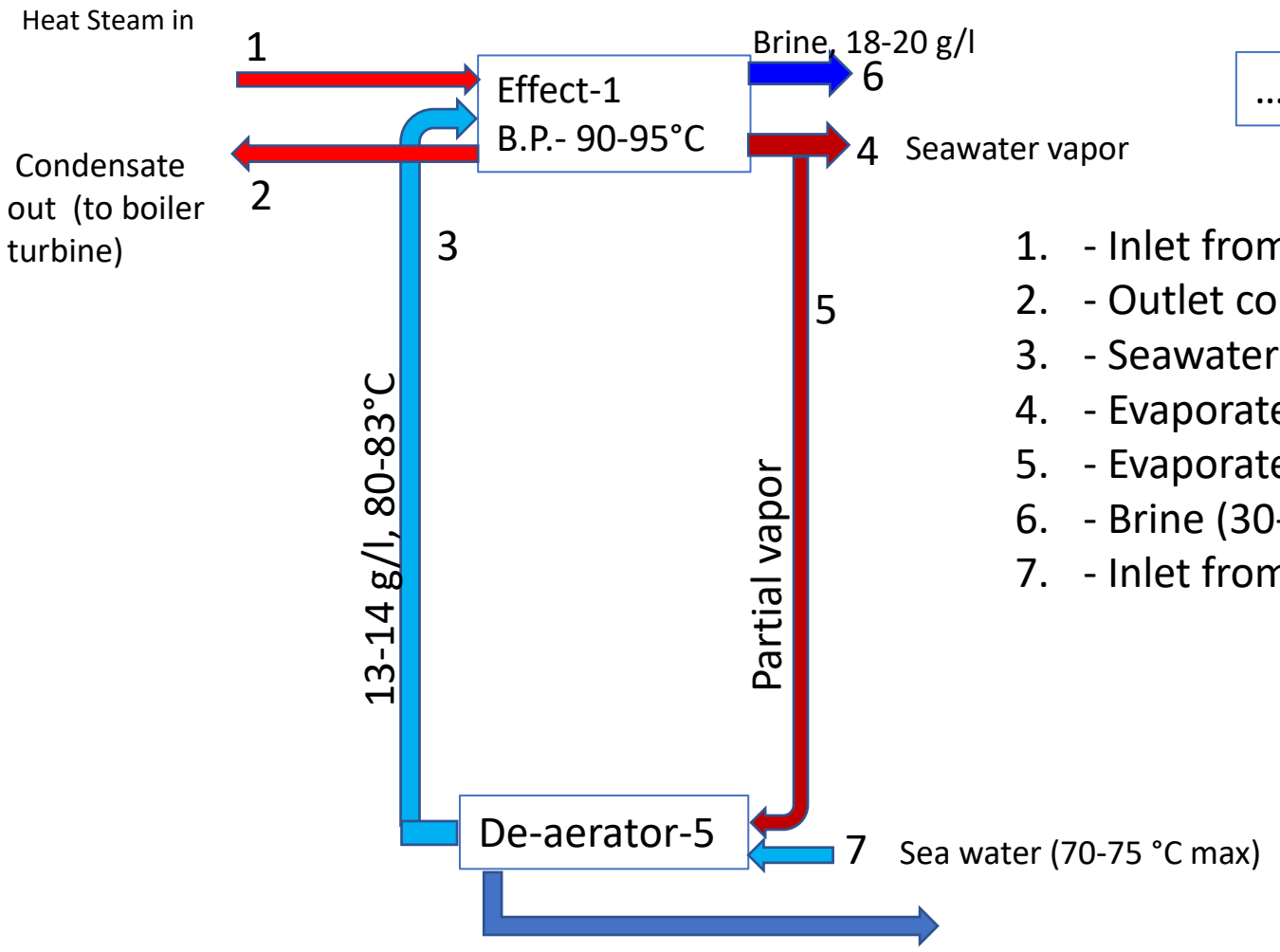


*1- Maintains constant amount of seed crystal on which salt from seawater deposits instead of heated surface

*2- Evaporation of seawater to max concentration of 50-60 g/l and boiling temperature of 115 °C for scale deposition

References:
F. P. Zaostrovsky et al., DISTILLATION DESALINATION PLANT IN THE CITY OF SHEVCHENKO. LAYOUT, EQUIPMENT AND OPERATING EXPERIENCE
E. P_ NOVIKOV. Et al., NUCLEAR INDUSTRIAL DESALINATION PLANT WITH FAST NEUTRON REACTOR AT SHEVCHENKO, verdfovsk Chenricut tl%gjncering Science Rescurch Institute. Sverdlovsk (U.S.S.R.) 1969
F. K. STANDIFORD AND H. F. BJORK, Evaporation of Sea Waterin Long Tube Vertical Evaporators, in: Saline Water Conversion, American Chemical Society, Washington D. C., (1960), p. 115..

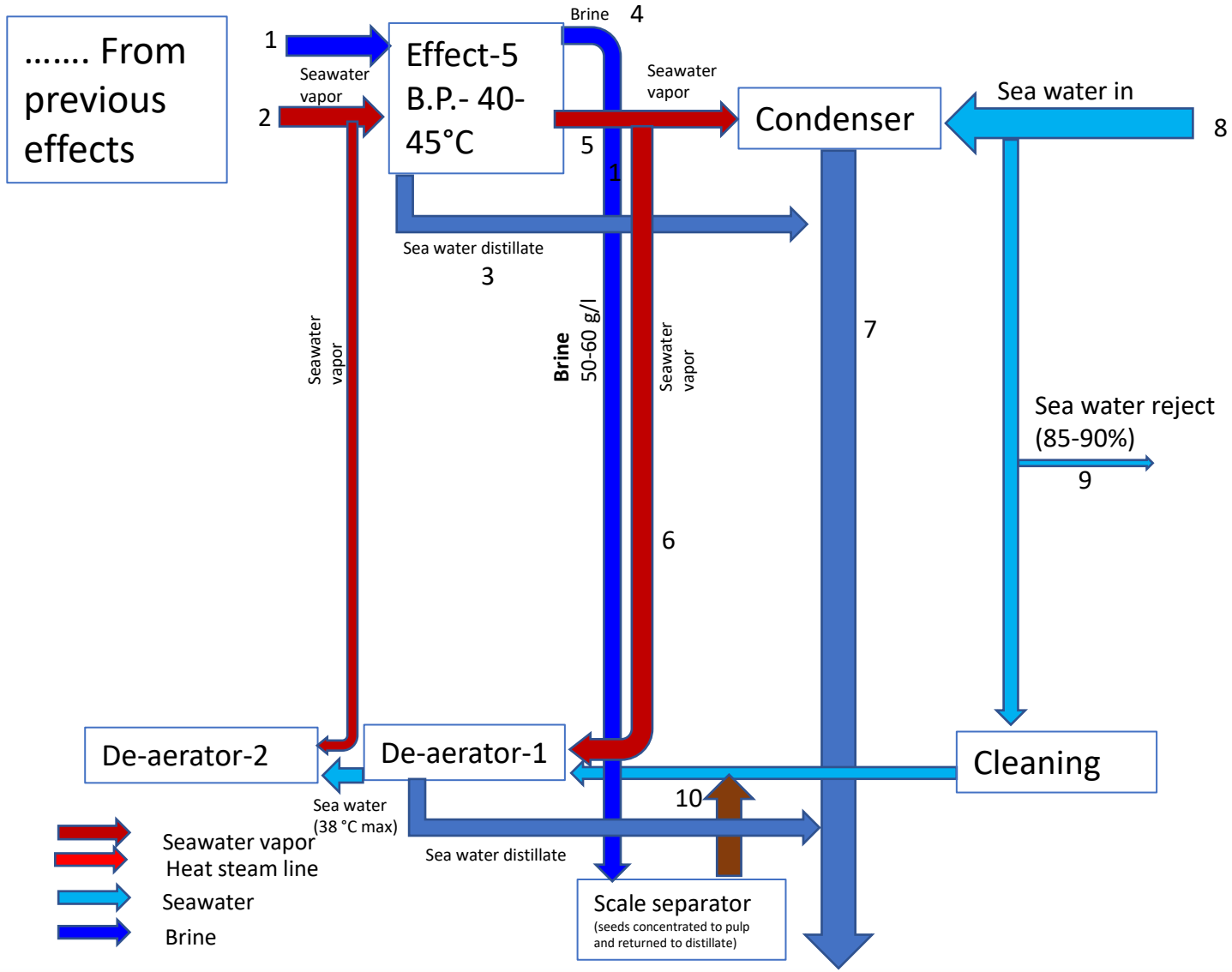
First Effect



……. To following effects

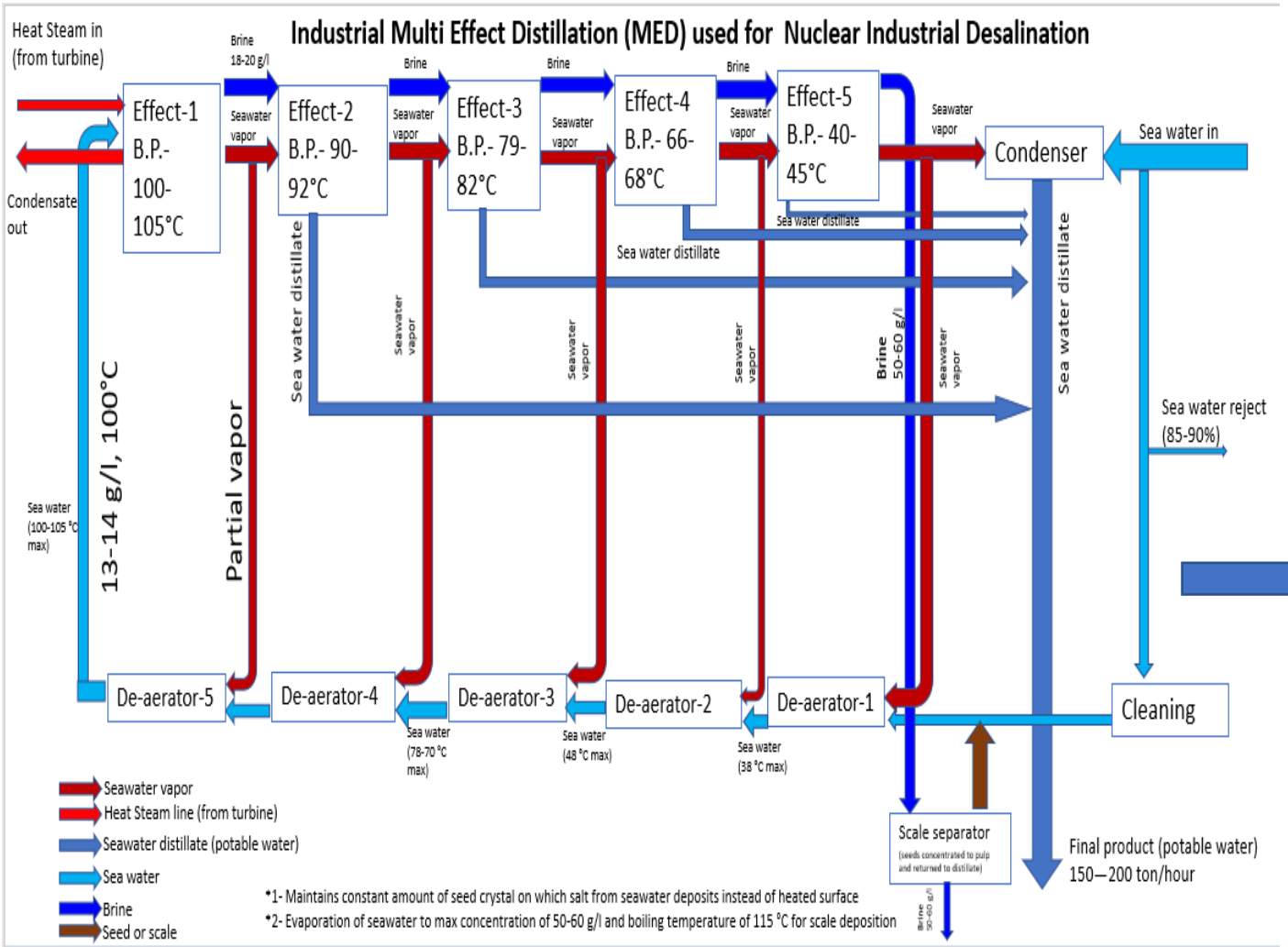
1. - Inlet from turbine
2. - Outlet condensate back to boiler
3. - Seawater in (13-14 g/l, 80-83°C)
4. - Evaporated seawater to effect 2
5. - Evaporated steam to deaerator/pre-heater
6. - Brine (30-35 g/l)
7. - Inlet from previous deaerator

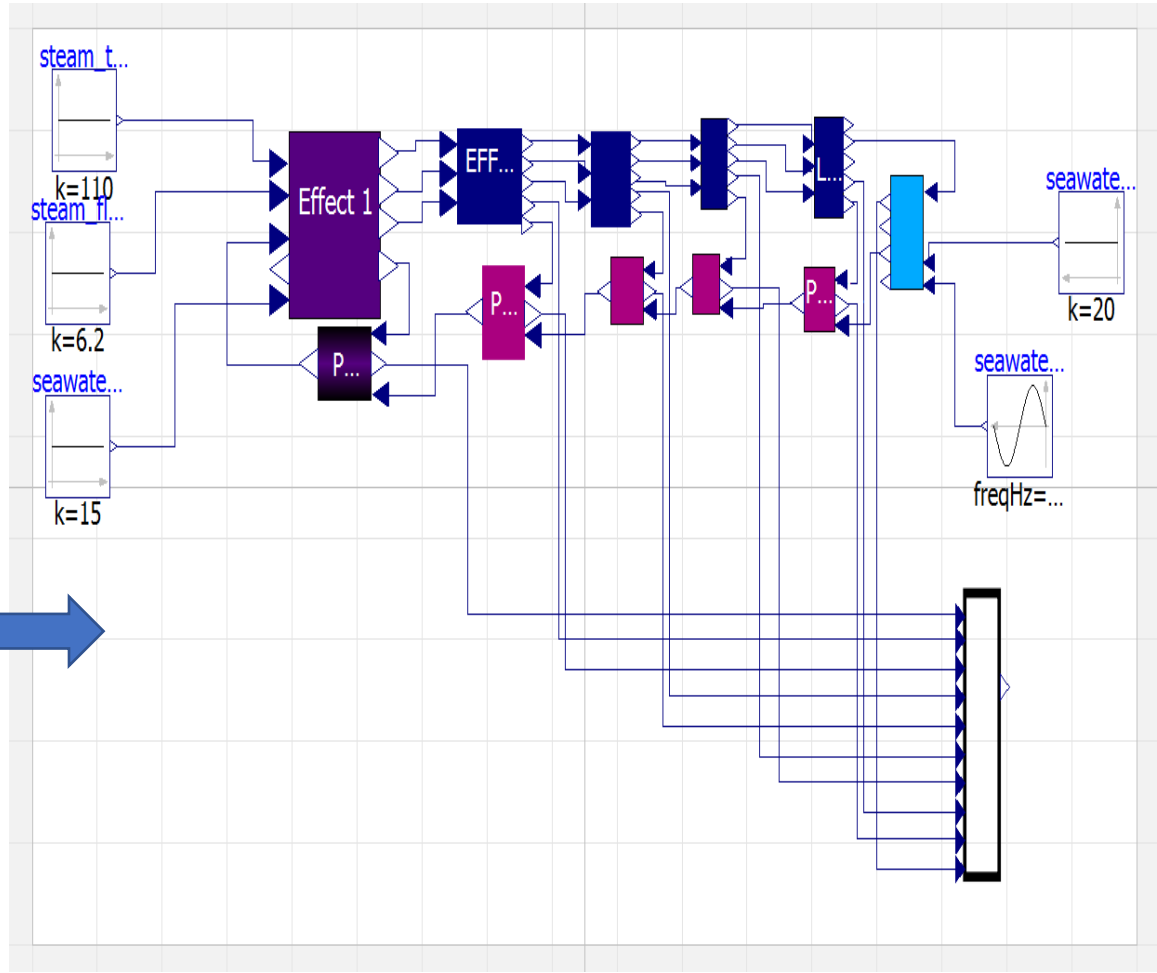
Last Effect



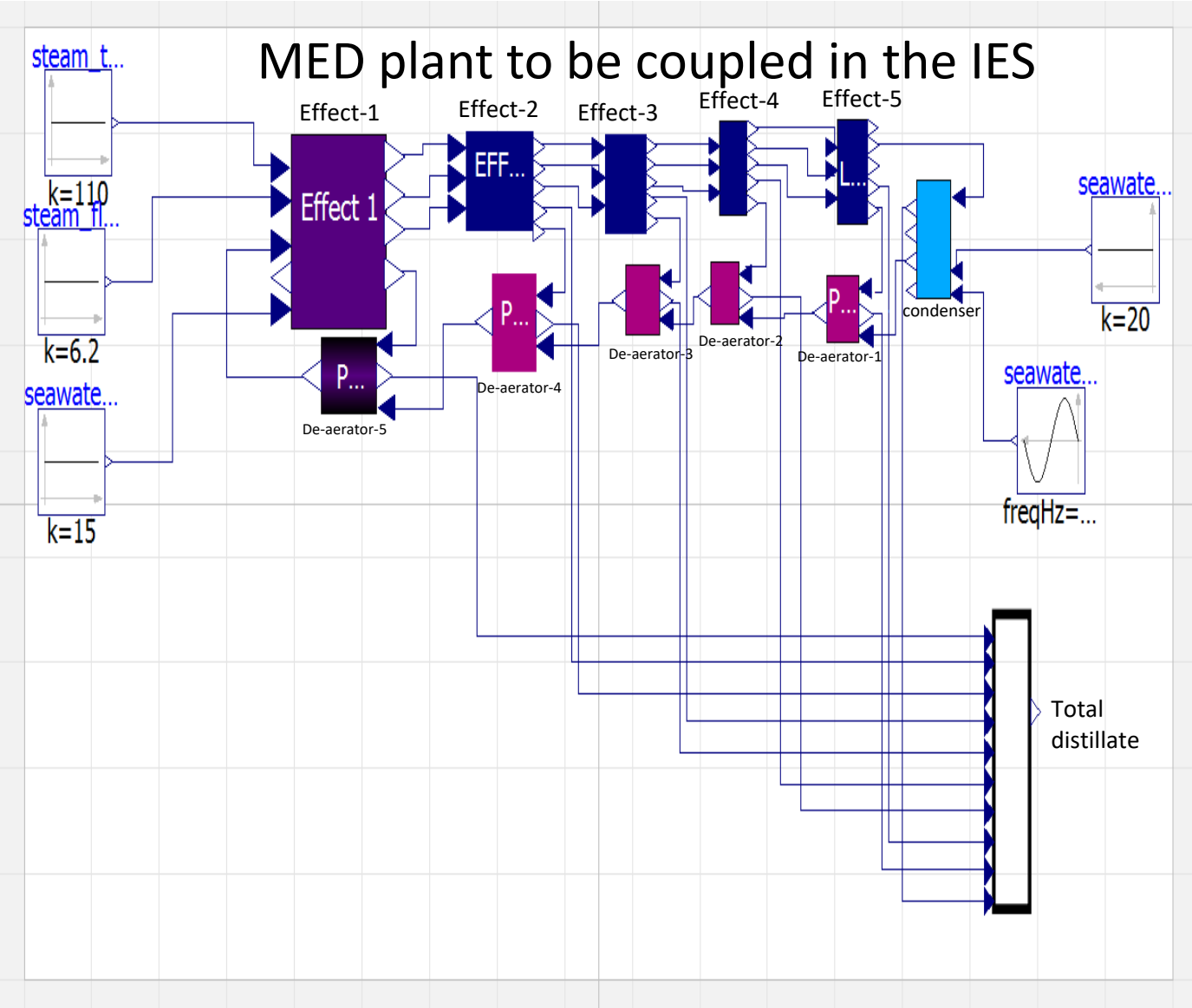
1. - Brine from previous effect
2. - Steam from previous effect
3. - Distillate formed in last effect
4. - Concentrated brine of last effect
5. - Steam formed in last effect
6. - Bypassed steam to deaerator
7. - Total distillate for potable processing
8. - Seawater into condenser
9. - Seawater rejected
10. -Scale added to seawater to catch crytals

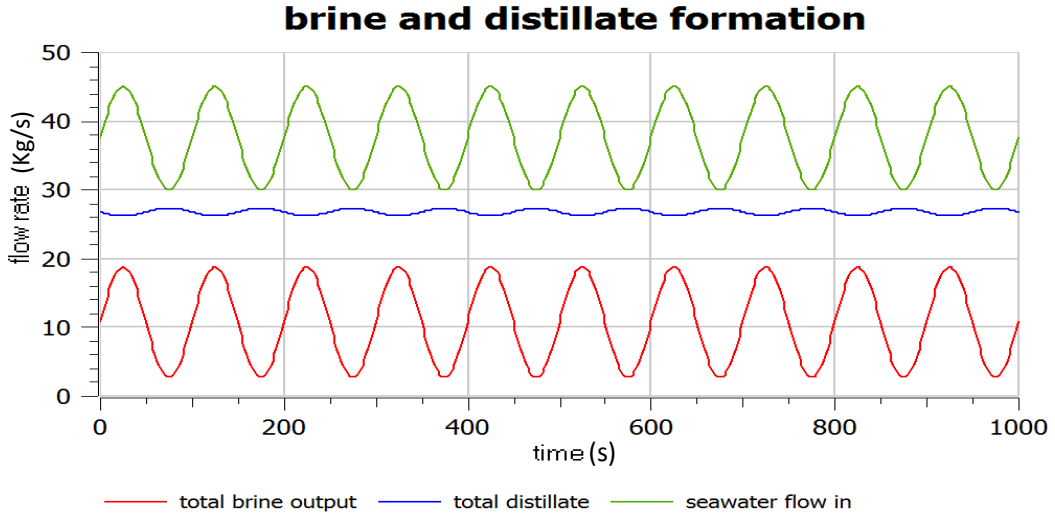
Modelica model

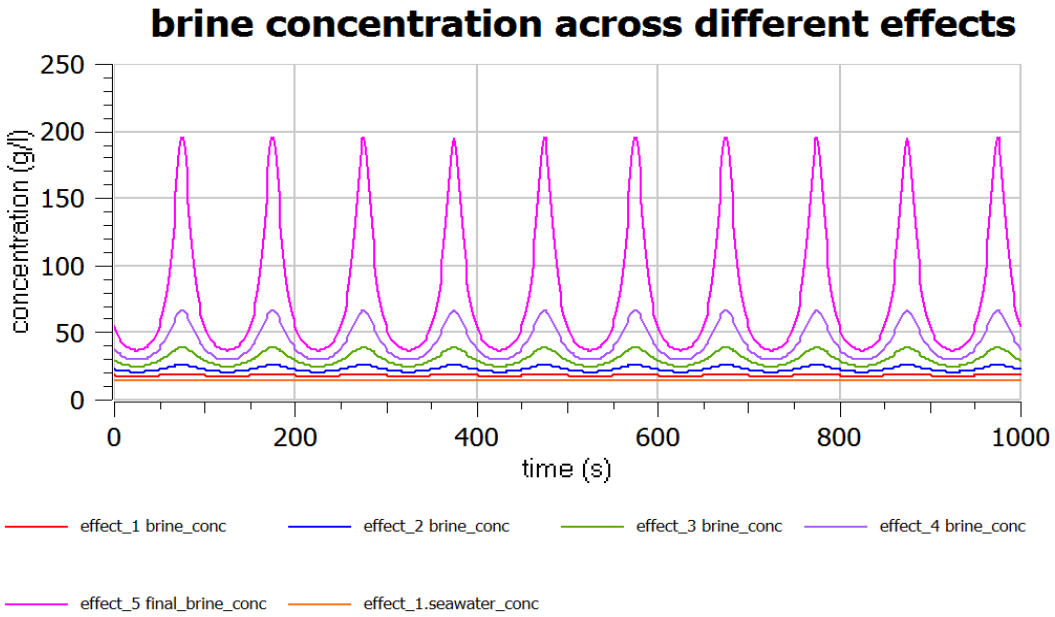




MED plant to be coupled in the IES







Conclusions

Effect	Boiling Temperature Atkau plant (˚C)	Boiling Temperature in Modelica model (g/l)	Concentration at Atkau plant (g/l)	Concentration in Modelica model (g/l)
1	100-105	100	18-20	18
2	90-92	90		23
3	79-82	79		29
4	66-68	66		37.5
5	44-45	44	50-60	55

With the similar boiling temperatures as in Shevchenko industrial plant:

- Plant operates with restrictions met (controller ensures that)
- Plant gives similar brine concentration outputs
- Distillate output can be matched to the plant by providing required seawater and steam and post processing in the potable water processing plant

Future work:

- Finish the controller design
- Integrate desalination plant to the current IES
- Model the physics and kinetics of the reactor in Modelica
- Develop an automated IES with the reactor

References

1. F. Zaostrovsky, Novikov, E., Shatsillo, V., Golub, S., Chernozubov, V., & Tkach, V. , "Distillation desalination plant in the city of Shevchenko. Layout, equipment and operating experience," *Desalination,* vol. 1, no. 2, pp. 165-177, 1966, doi: https://doi.org/10.1016/S0011-9164(00)84016-3.

2. E. Novikov, Chernozubov, V., & Golub, S., "Nuclear Industrial Desalination Plant with Fast Neutron Reactor at Shevchenko," *Desalination,* vol. 1, no. 6, pp. 349-367, 1969, doi: https://doi.org/10.1016/S0011-9164(00)80225-8.

Thank You