Thermal Energy Storage for TEPLATOR: Technology, Utilisation And Economics

CZECH TECHNICAL UNIVERSITY IN PRAGUE

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Abstract

Generally, energy storage is a very current topic nowadays as renewable sources of energy produces more cheap but unpredictable energy. Energy storages became more and more common not even for electric but also for heat. Thanks, cheap energy, stronger and smarter control systems and consumption predictions energy storage is becoming not only as needed solution but also as a wanted solution even as energy storage for district heating. TEPLATOR (Fig. 1.) is a critical assembly using already irradiated nuclear fuel from commercial light water power reactors which is not burnt up to its regulatory and design limits. This innovative concept for district heating could benefit from having a decent heat energy storage for compensation of: 1) TEPLATOR power fluctuations, 2) Compensation and smoothing of the demand curve and 3) can serve as an emergency and safety heat sink. Thermal energy storage (TES) is a promising solution, which operates in a suitable temperature range, could absorb adequate amount of heat in reasonable material volume and with good operation dynamics providing quick response for charging and discharging demands. In this paper we would like to point out and discuss benefits and possibilities of Thermal energy storage operating with TEPLATOR.

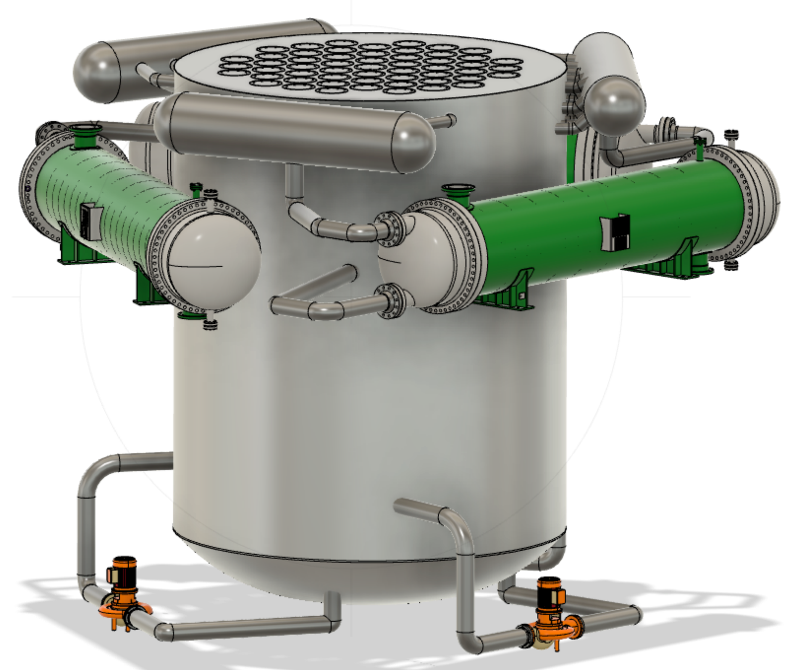

Fig.1.TEPLATOR 3D visualization [1]

Thermal Energy Storage (TES) connected to TEPLATOR secondary circuit as a compensator power fluctuations on production site and compensation and smoothing of the demand curve on consumption site in short term (minutes / hours) or long term.

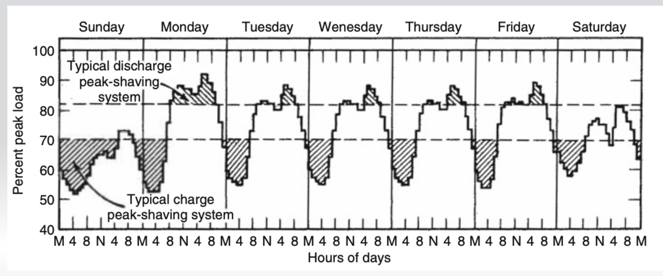

Fig.2. Peak shaving [2]

TES can also serve as an emergency and safety heat sink, for residual heat removal system (RHRS), after reactor shut down (scheduled e.g. for service and inspection or emergency one). Natural convection in primary circuit and secondary circuit is anticipated. Cooling of TES is anticipated only by heat loos to environment (assuming active TES cooling and heat distribution and heat dissipation in distribution grid not operating).

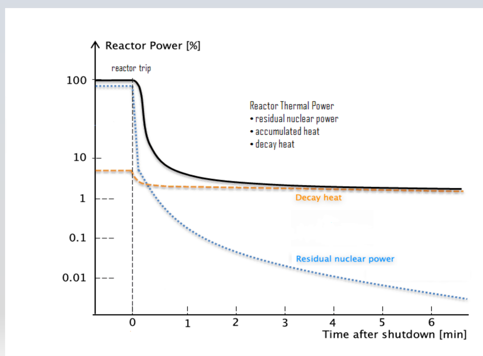

Fig.3. TEPLATOR Residual heat

Latent heat storage

By using latent storage instead of sensible storage, the specific volume demand can be reduced of a factor 5 [3]. The main advantage of LHTES is the higher energy density, which allows storing the same amount of energy by using smaller volumes of material. Also, only one storage tank is needed, instead of two tank solution for SHTES. Lower space and material requirements, are compensated with higher heat storing material price and need for more enhanced construction of the storage tank (e.g. fins for better heat transfer) Furthermore, some experiments shows that heat losses in LHTES are significantly lower in comparison to an equivalent SHTES. LHTES are generally suitable for systems with low temperature difference between outgoing and returning streams. With higher temperature gradient more phase changing materials need to be involved, this leads to more complicated construction and significant rise of construction and operation costs. Possible materials for Latent heat storage operating together with TEPLATOR is listed in (Tab 1.). General layout scheme is displayed on (Fig.4.).

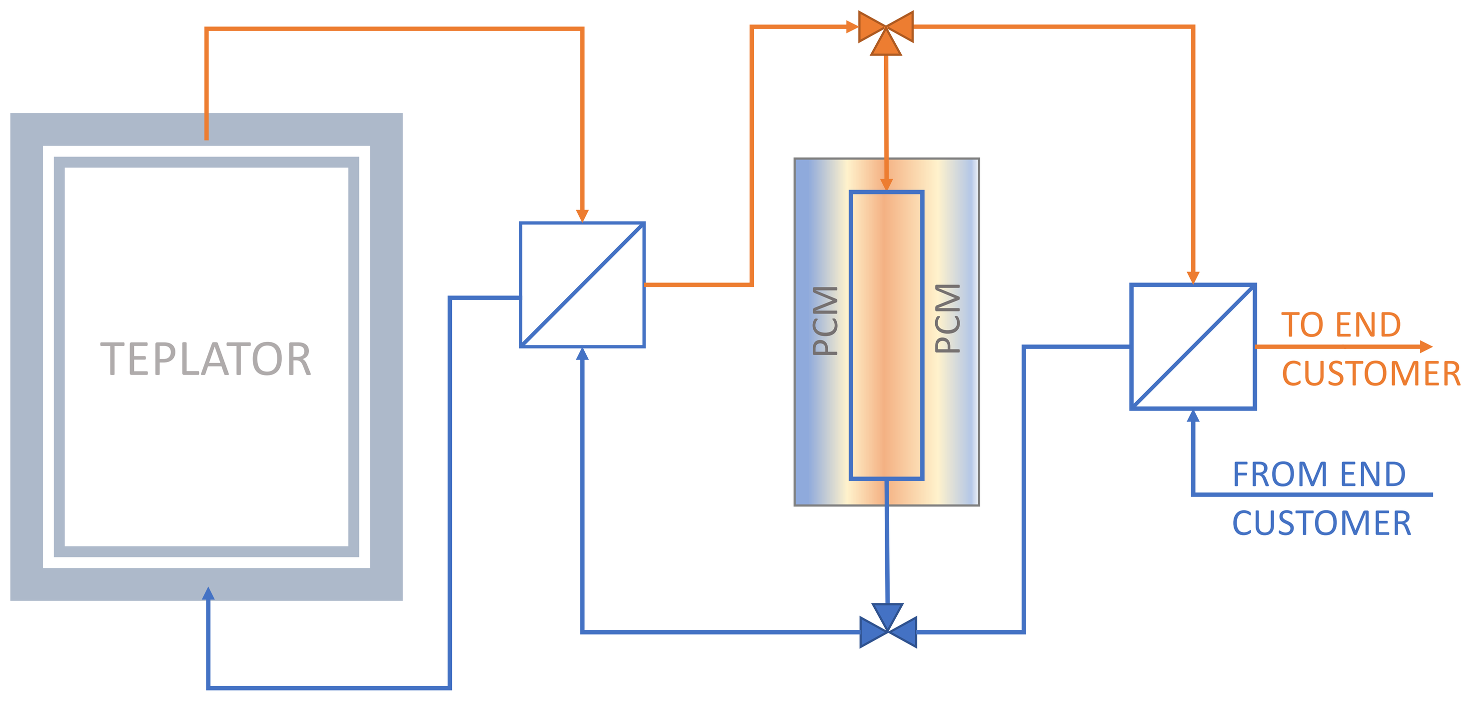

Fig.4. Latent heat storage operating with TEPLATOR 3D general layout scheme.

Tab 1. Salt hydrates for latent heat storage [4]

Salt hydrates	Melting temp. [°C]	Heat of fusion [J. g^{-1}]	Specific heat (solid) [kJ.kg^{-1}.K^{-1}]	Density [kg.m^{-3}]	Thermal conduct. [W.m^{-1}.K^{-1}]	Latent heat storage capacity [MJ.m^{-3}]
$Al(NO_3)_2 \cdot 8H_2O$	89.3	150	-	-	1.17	-
$Mg(NO_3)_2 \cdot 6H_2O$	89.9	163	0.669	1636	1.81	266,7
$NH_4Al(SO_4)_2 \cdot 12H_2O$	95	269	-	1650	1.71	443,9

Sensible heat storage

In comparison with LHTES, SHTES are more flexible, easy to build and operate. Temperature of stored material (hot tank) could be easily changed in short or long term, without need of replacing the storage material. On the other hand, SHTES are characterized with lower heat storing density and larger storage tanks.

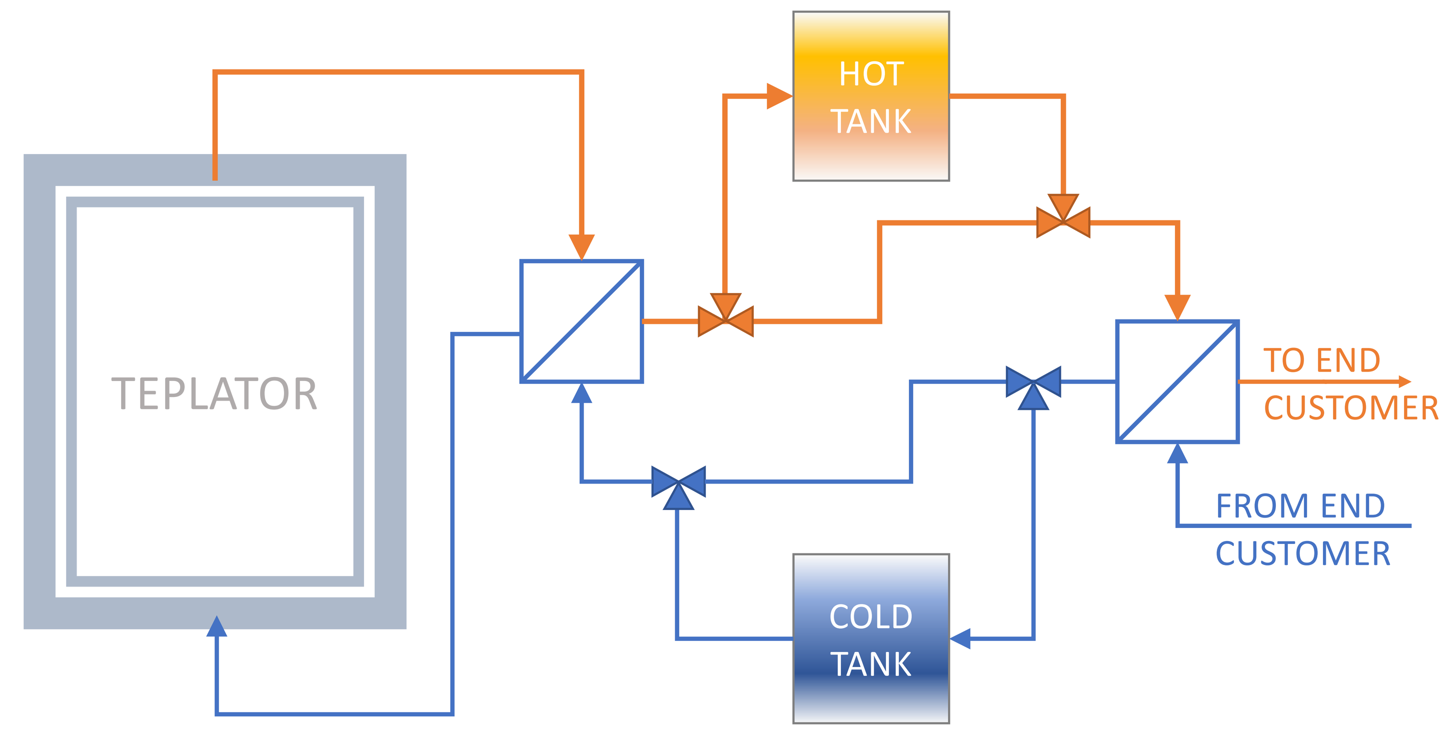

Fig.5. 2-Tank sensible heat storage operating with TEPLATOR – general layout scheme

There are two storage tanks concepts: A/ 2-Tank storage (Fig.5.), having hot and cold storage tank. Where hot tank is being charged by heated heat transfer fluid and cold tank, where depleted HTF is stored. And B/ one tank Thermocline system (Fig.6), where hot and cold HTF is separated with floating barrier or tank is filled with material restricting vertical movement of the fluid.

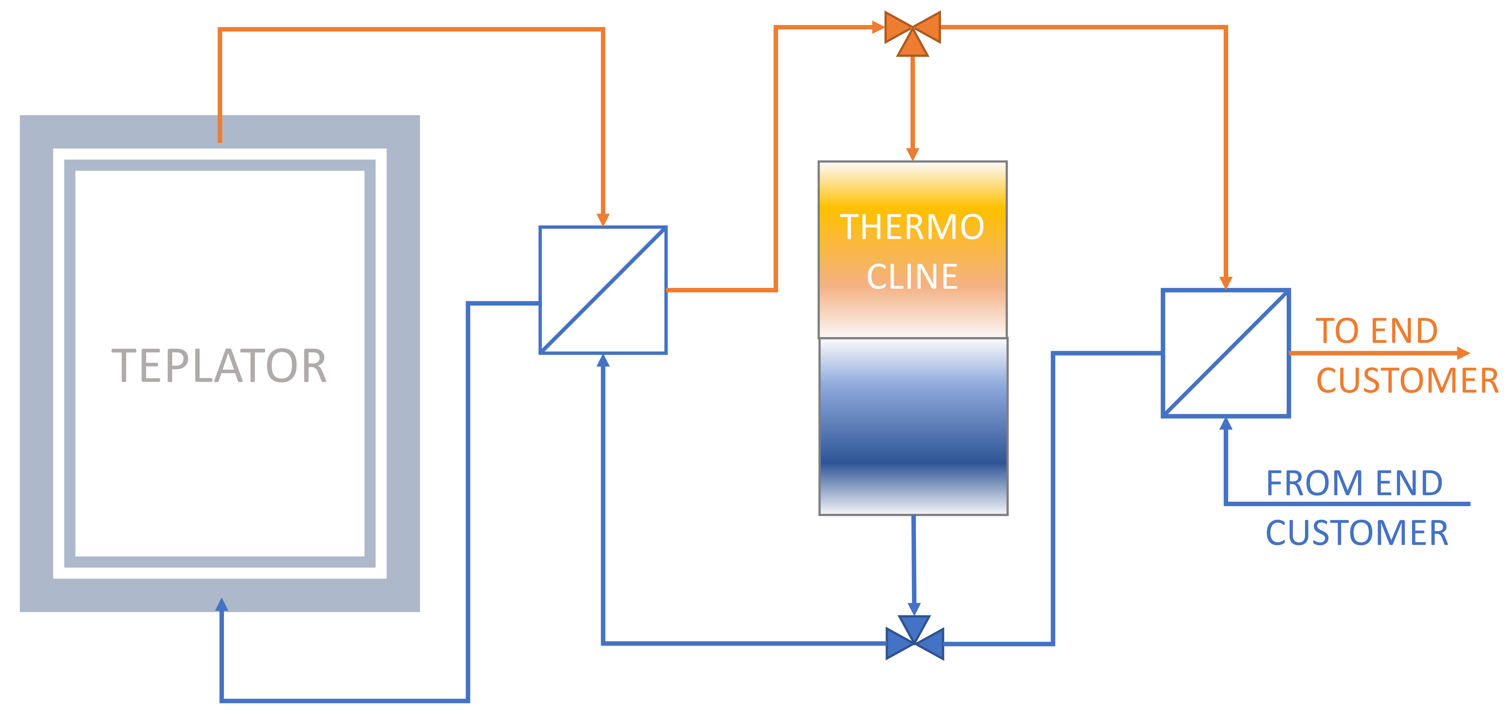

Fig.6. Thermocline sensible heat storage operating with TEPLATOR – general layout scheme

For sensible heat storage at temperatures above 100 °C molten salts are most suitable. Advantages of molten salts (Tab.2.) are the high thermal stability, relatively low material costs, high heat capacity, high density, non-flammability and low vapor pressure

Tab 2. Molten salts for sensible storage [5]

Salt	Melting temp. [°C]	Maximal temp. [°C]	Specific heat [kJ.kg^{-1}.K^{-1}]	Density [kg.m^{-3}]	Thermal conduct. [W.m^{-1}.K^{-1}]	Sensible heat storage capacity [MJ.m^{-3}.K^{-1}]
HITEC $NaNO_3$-KNO_3-$NaNO_2$ (7 – 53 – 40)	142	535	1.561	1640	0.60	2.56
HITEC XL $NaNO_3$-KNO_3-$Ca(NO_3)_2$ (7 – 45 – 48)	120	500	1.447	1992	0.519	2.9
Solar salt $NaNO_3$-KNO_3 (50-50)	220	600	1.5	1899	0.55	2.8
$LiNO_3$	250	600	-	2380	-	-

Latent vs Sensible heat storage

Latent heat storage

- Higher storage capacity
- Lower construction cost
- Lower heat loss
- More suitable for lower temperature gradient

Sensible heat storage

- More suitable for higher temperatures
- Lower operation and service cost
- Faster system response
- Easier construction and engineering requirements

Conclusions

- Thermal energy storage can serve for TEPLATOR's **residual heat removal**.
- Thermal energy storage could provide enough capacity to allow TEPLATOR's full power operation while **covering the changes in heat consumption**.
- Construction and design of TES is strongly dependent on primary circuit temperatures as well as on operation temperatures in district heating grid.
- **Sensible heat storage with molten salt** as heat transfer / heat storing fluid is optimal for TEPLATOR operating above 100 °C (with SANTOWAX primary circuit coolant) .
- **Latent heat storage with water solution of salt hydrates** is optimal for TEPLATOR operating at temperatures below 100 °C.

References

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