ANALYSIS OF THERMAL ENERGY STORAGE SOLUTIONS FOR A 1 MW CSP-ORC POWER PLANT

David Sánchez, Hicham Frej, Gonzalo S. Martínez,
José María Rodríguez, ***El Ghali Bennouna***

3rd International Seminar on ORC Power Systems,
October 12-14, 2015, Brussels, Belgium

aicia

UNIVERSIDAD DE SEVILLA

GMTS | GRUPO DE MAQUINAS Y MOTORES TERMICOS DE SEVILLA

IRESEN
Institut de Recherche en Energie Solaire et en Energies Nouvelles

IRESEN Institut de Recherche en Energie Solaire et en Energies Nouvelles | GMTS GRUPO DE MAQUINAS Y MOTORES TERMICOS DE SEVILLA | UNIVERSIDAD DE SEVILLA | aicia

Content

GMTS GRUPO DE MAQUINAS Y MOTORES TERMICOS DE SEVILLA

Introduction

Why a Solar-ORC System?

- Applicable to medium size power plants (<5MW);
- Not much capital intensive, faster to deploy;
- Simpler than conventional steam cycle;
- Low pressure/ low cost piping;
- Firmer dispachability than PV;
- Good part-load generation application…

Why a Thermal Storage System?

- Increased power production;
- Lower LCOE (electricity generation cost);
- Possible production extension to night time;
- more stable heat supply…

SOLTIGUA Linear Fresnel Collector

EXERGY radial outflow turbine

Methodology:

CSP-ORC plant description

Gross Power Output: 1 MWe

Estimated Production: 1,5 GWh/yr (DNI Benguerir: 2100 kWh/m²/y)

Land usage: ~2.5 Hectares without storage, ~3.5 Hectares for with storage.

	Classical steam-CSP	CSP-ORC
Solar technology	PTC collectors	Linear Fresnel
Cooling medium	Water	Air
Foot print	2,5ha for 1MWe	2,2ha for 1MWe
CO_2 equivalent	1000t/ year	1000t/ year
Water Consumption	Over 10000m^3/ year	0m^3/ year
operation	manned	unmanned
Type of HTF fluid	Synthetic oil	Mineral oil

Solar Field

Heat transfer fluid: Delcotherm E15

Rated DNI: 850kW/sqm

Heat output: 5000kW$_{th}$

Power Block

Working Fluid: Cyclopentane

Inlet temperature 300 C

Outlet temperature 180 C

Ambien Air

Cooling medium: air

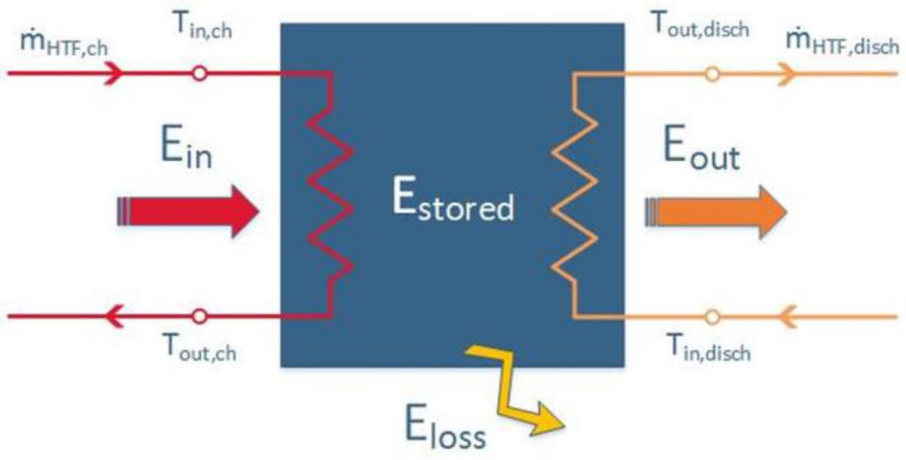
Ambient temperature range 10C to 45C

Methodology:

Thermodynamics of heat storage

$$\eta_{TES,charging} = E_{stored}/E_{in} \qquad \eta_{TES,discharging} = E_{out}/E_{stored}$$

$$\eta_{TES,overall} = \eta_{TES,charge} \times \eta_{TES,discharge} = E_{out}/E_{in} = 1 - E_{loss}/E_{in}$$



Scheme of an elementary TES system

- **Energy being supplied to the system;**
- **Energy that can be delivered back by the system;**
- **Energy that was initially in the system;**
- **Energy that is lost the surroundings;**
- **Residual energy not being delivered by the storage system.**

Methodology:

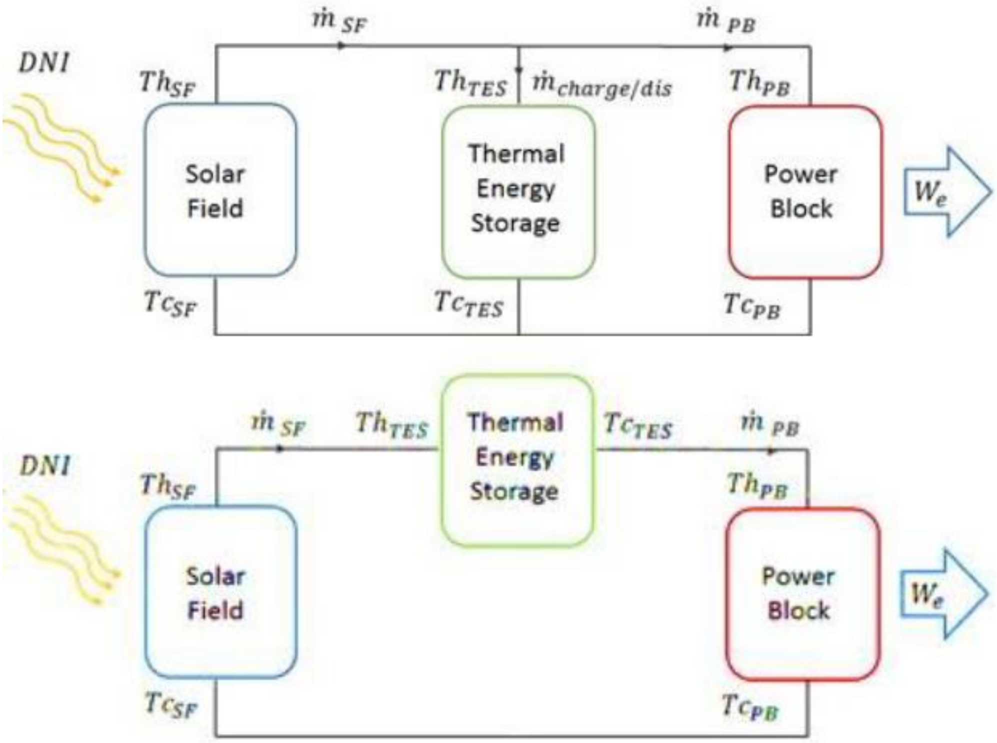
Possible storage configurations for CSP

Parallel configuration

- Allows a separation between the storage and the rest of the plant.
- Allows for higher temperatures within the storage.
- More operation flexibility.

Series configuration

- Preferred for latent heat storage systems.



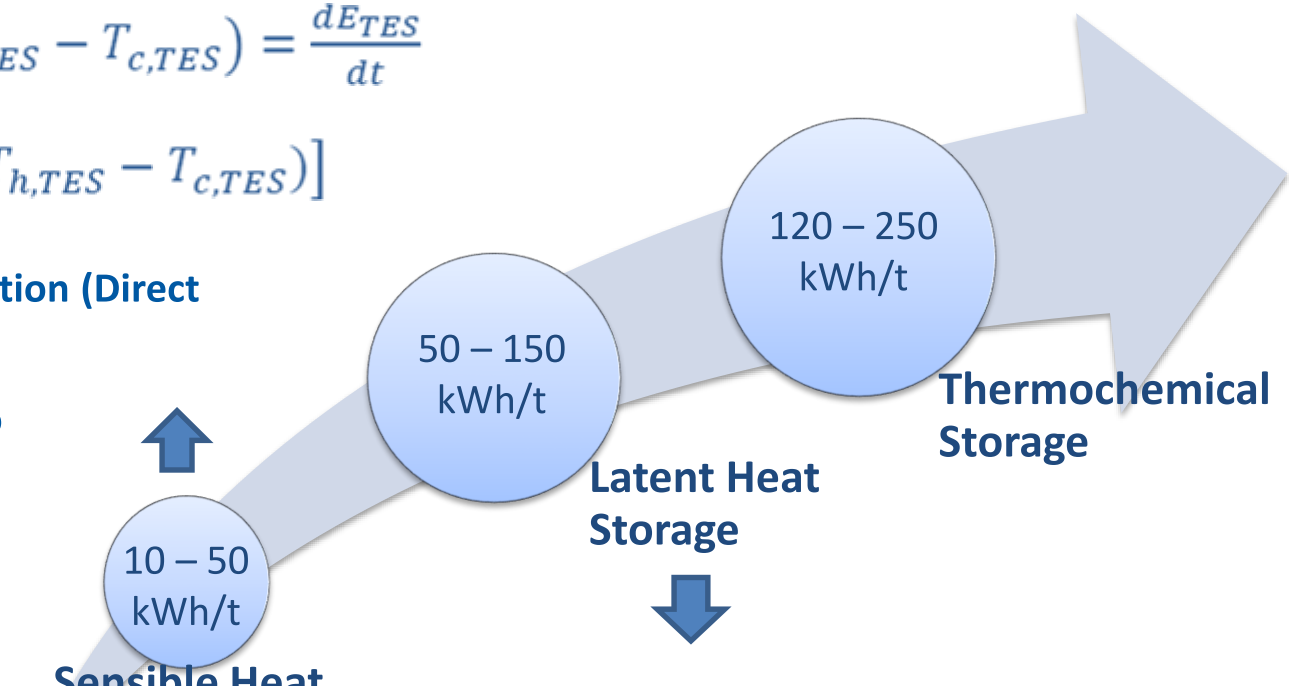
TES system integration layouts: parallel (top) and series (bottom).

Methodology:
Thermal storage technologies

$$\dot{Q} = \dot{m}_{TES}\, C_{p,TES}(T_{h,TES} - T_{c,TES}) = \frac{dE_{TES}}{dt}$$

$$\dot{Q} = \frac{d}{dt}[M_{TES}\, C_{p,TES}(T_{h,TES} - T_{c,TES})]$$

- **Two tanks HTF configuration (Direct System)**
- **Classical molten salt two tanks configuration (Indirect System)**
- **Single tank thermocline system with filler material (Direct System)**

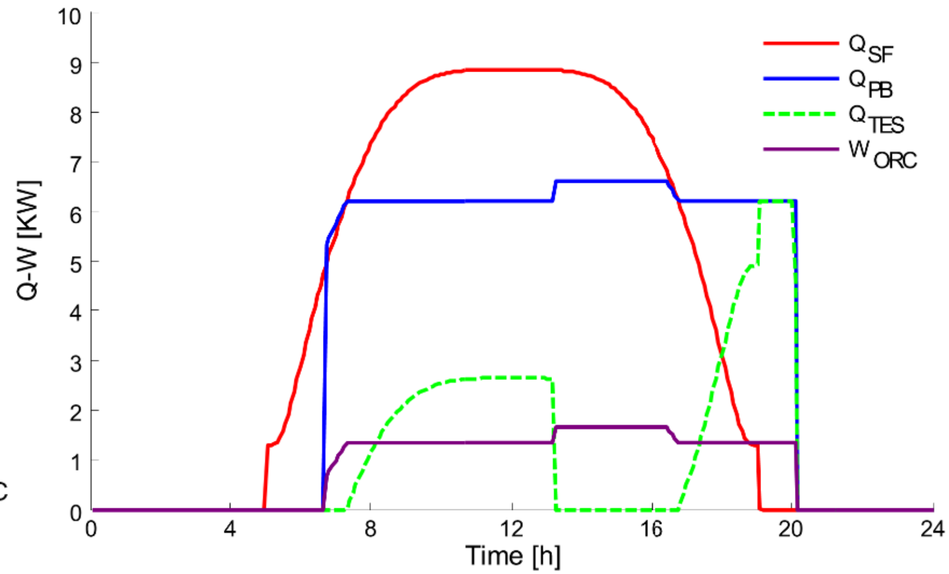


- **Single tank with encapsulated PCM's for Heat Storage (Indirect System)**

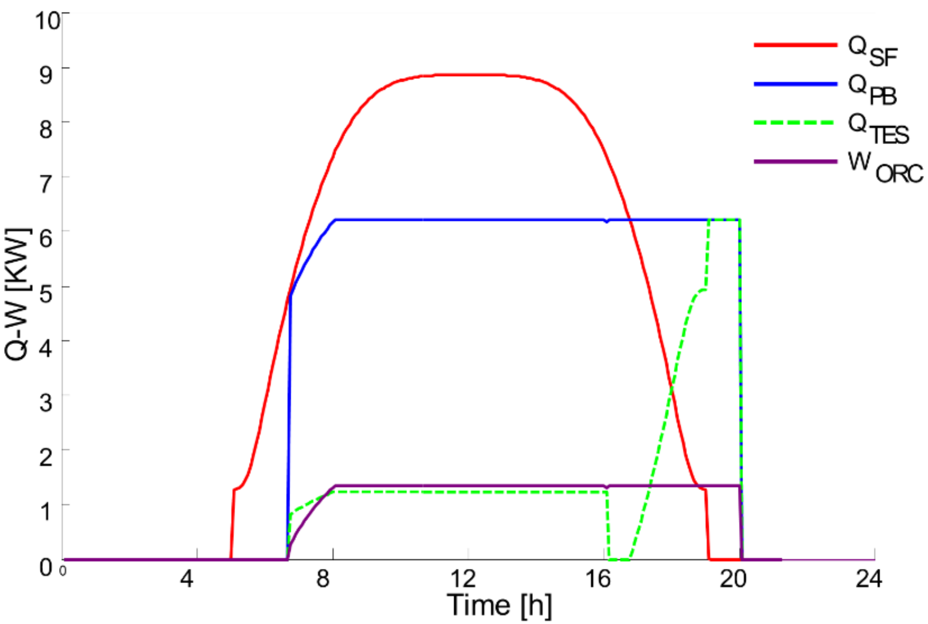
$$\dot{Q} = \dot{m}_{TES}\; \lambda_{PCM} = \frac{dE_{TES}}{dt} = \frac{d}{dt}[M_{TES}\, \lambda_{PCM}]$$

Results:

Daily simulation results



Daily performance of the direct sensible heat TES system (right) and indirect latent heat TES system (bottom).



Main parameters

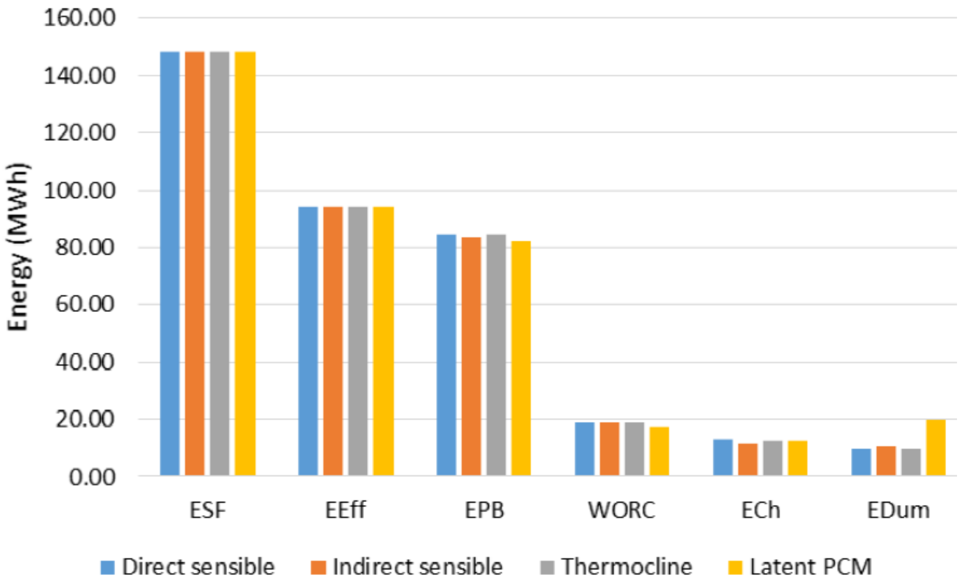
- Heat from the solar field,
- Heat from/to the storage system;
- Heat to the power block;
- Electric yield.

Results:

Overall technologies comparison

Main remarks

- Larger amount of energy is dumped with indirect and latent systems;
- Higher system density for indirect and thermocline systems;
- Lower average Power Block efficiency for the latent heat system;
- Electric yield.



	Direct sensible	Indirect sensible	Thermo -cline	Indirect latent
Average PB efficiency (%)	22,25	22,29	22,13	21,23
Storage medium volume (m^3)	420	315	200	125

Comparison of daily TES operation parameters:

- **Energy collected by SF "ESF";**
- **Energy on the HTF "EEff";**
- **Energy to the ORC "EPB";**
- **Electric production "WORC";**
- **Energy to the TES "Ech";**
- **dumped energy "EDum".**

Conclusions

The main conclusions drawn from the work presented here are:

- Sensible heat storage systems enable faster charging processes and more agile operation;
- Latent heat systems exhibit poorer thermodynamic performance in comparison with sensible heat storage;
- Direct sensible heat storage systems request a prohibitive amount of storage medium;
- Latent heat systems require the lowest amount of storage medium;
- Thermocline storage steps forward as the most leveraged solution.

Thanks for your attention

El Ghali Bennouna

Thermal storage systems

....

Mobile : + 212 (0) 620 30 75 10
Fax : + 212 (0) 537 68 88 52
E-mail : bennouna@iresen.org
Skype : ben.elg

....

Research Institute on Solar Energy and New Energies (IRESEN)
Quartier Administratif BP 6208
Rabat-Instituts Agdal – Rabat, Morocco

....

www.iresen.org

aicia

GMTS | GRUPO DE MAQUINAS Y MOTORES TERMICOS DE SEVILLA

UNIVERSIDAD DE SEVILLA

IRESEN
Institut de Recherche en Energie Solaire et en Energies Nouvelles