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Optimizing thermal energy storage operation

Mohammad Abutayeh *, Anas Alazzam, Bashar El-Khasawneh

Khalifa University, PO Box 127788, Abu Dhabi, United Arab Emirates

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Abstract

Thermal energy storage systems are usually attached to solar power plants to extend their operation beyond sunshine periods. Solar heat collected during the day is divided between a power block and a properly-sized thermal energy storage system. The stored heat is later released to be processed by the power block during periods of little or no solar resource. An operating scheme for a dual-tank molten salt thermal energy storage system was developed. The scheme can be used to optimize charging and discharging processes of a thermal energy storage system to maximize power generation or revenue.

Keywords: Solar energy; Concentrated solar power; Thermal energy storage

1. Introduction

Oil drilling involves the release of sizeable quantities of natural gas, most of which is captured and sold separately. There are many occasions where the amount of natural gas released from oil wells exceeds the capacity of its capture. There are also occasions when the gas capturing apparatus is out of service while oil pumping is ongoing. Excess natural gas is usually burned off with its potential energy dissipating to the ambient, a standard procedure in the oil industry. The energy of that excess natural gas could be stored and released at a more appropriate time using a thermal energy storage (TES) system attached to the natural gas processing plant.

Concentrated solar power (CSP) plants produce electricity using generators attached to turbines supplied with pressurized solar-generated steam. Sunbeams are focused onto a small aperture producing large amounts of heat that is used to generate steam to drive the turbines of conventional Rankine cycle power plants. The sporadic nature of solar energy would normally result in a varying electrical output corresponding to varying solar radiation intensity levels. However, integrating a properly-sized TES system with these solar thermal power plants will guarantee a continuous and smooth supply of electricity conforming to a desired power output profile. The TES system can be thermally charged during high radiation periods then it can be thermally discharged at night and during low radiation periods or cloud covers thus streamlining the electric output of the plant by regulating its thermal energy input.

The most common TES system is the dual-tank molten salt scheme shown in Fig. 1 as an integrated part of a CSP plant. The system consists of two equally-sized well-insulated tanks holding molten salt at two different temperatures. Each tank has a pump connected to its outlet pipe to push molten salt out as well as an inlet pipe to let molten salt in. Furthermore, a heat exchanger is placed between the two tanks designed to transfer heat from the solar field (SF) to the TES system as well as from the TES system to the power block (PB) via a heat transfer fluid (HTF).

* Corresponding author. Tel.: +971 2 501 8470; fax: +971 2 447 2442.
E-mail address: mohammad.abutayeh@kustar.ac.ae (M. Abutayeh).

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Nomenclature

A	ambient
AUX	auxiliary heater
Capacity	thermal capacity, MW h
CSP	concentrating solar power
Cost	running cost, \$/MW h
D	diameter, m
DNI	direct normal irradiance, W/m^2
h	enthalpy, kJ/kg
HTF	heat transfer fluid
L	length, m
m	mass flow rate, kg/s
M	mass, kg
PB	power block
PPA	power purchase agreement
Price	remuneration rate, \$/MW h
q	heat flow, MW
Q	heat, MW h
Revenue	plant revenue, \$
SA	surface area, m^2
SF	solar field
SOC	TES state of charge, percent
t	time, h
T	temperature, °C
TES	thermal energy storage
U	heat transfer coefficient, MW/m^2 °C
v	volumetric flow rate, m^3/s
V	volume, m^3
w	power generation, MW
Z	tank level, m
Δt	time increment, h
ρ	density, kg/m^3

Adding heat to the TES system is termed charging, while withdrawing heat from the TES system is termed discharging. During the TES charging process, molten salt is pumped from the cold tank to the hot tank through a heat exchanger where hot HTF coming from the SF gives up some of its heat to the passing molten salt. Whereas, during the TES discharging process, molten salt is pumped from the hot tank to the cold tank through a heat exchanger where the molten salt gives up some of its heat to the passing cold HTF bound for the PB. The flow rate of molten salt in both processes is modulated to control its bound tank temperature.

Thermal energy storage systems are very well insulated; nonetheless, molten salt is constantly losing small amounts of its heat to the ambient because of the large temperature gradient across the surface of the holding tanks. Consequently, auxiliary heaters (AUX) are always attached to thermal energy storage systems to prevent salt

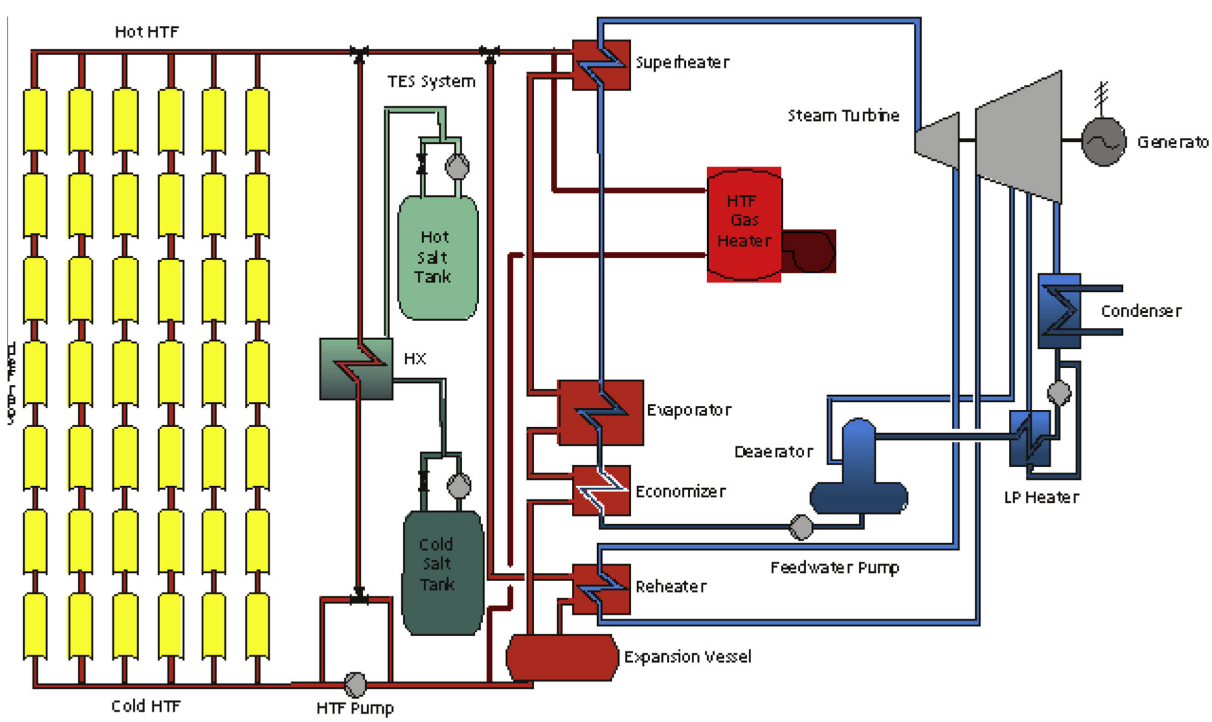

Fig. 1. Dual-tank molten salt scheme in a CSP plant.