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SMALL-SCALE CSP PLANT COUPLED WITH AN ORC SYSTEM FOR PROVIDING DISPATCHABLE POWER: THE OTTANA SOLAR FACILITY

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THE OTTANA SOLAR FACILITY

Location: Ottana (Italy)

Geographic coordinates:

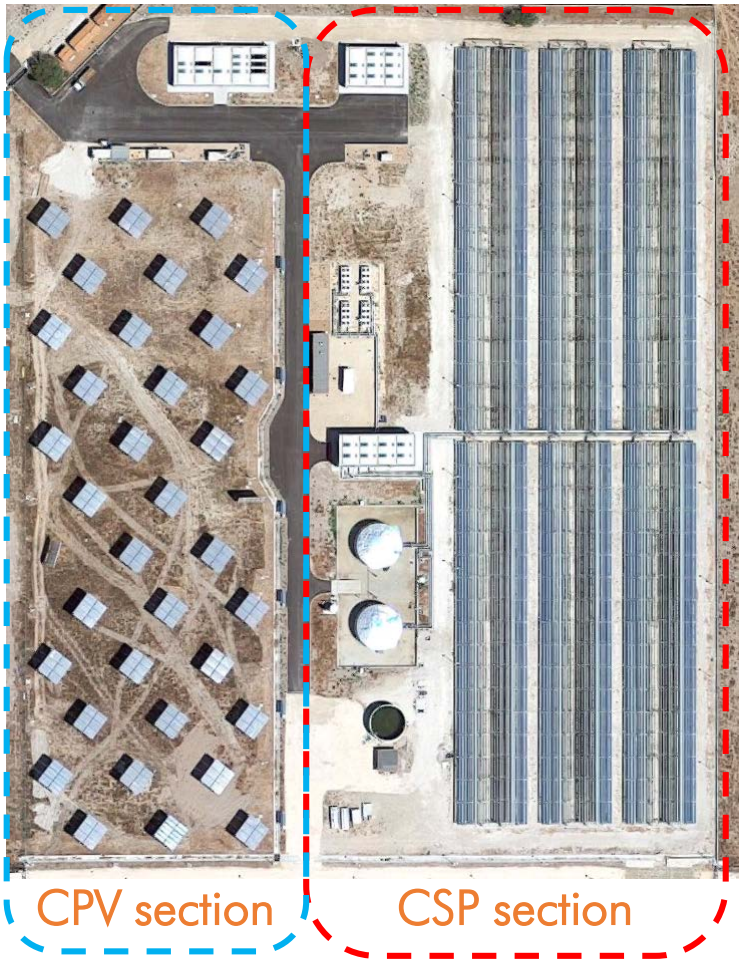
40° 14.25 N - 8° 59.63 E

Available solar energy:

1800 kWh/(m^2·yr).

Funder: Regional Government of Sardinia

Customer: ENAS (Sardinia Water Authority) Ente acque della Sardegna



CSP section:

- Solar Field - linear Fresnel collectors
- TES section - two-tank direct system
- Power block - ORC unit

CPV section:

- CPV panels with biaxial solar trackers
- Battery bank - Sodium-Nickel batteries

THE OTTANA SOLAR FACILITY

Solar Field:
- number of loops: 6
- total collecting area: 8592 m^2,
- reference thermal output: 4690 kW_{th};
- HTF inlet temperature: 165 °C
- HTF outlet temperature 275 °C

TES system:
- Two-tank direct TES system
- HTF: Therminol SP mineral oil
- Mass of stored oil: 190 t
- storage capacity: 15.2 MWh

CPV system:
- Nominal Power: 430 kW_p (under CSTC)
- Nominal efficiency: 29,8%
- Number of trackers: 36
- Number of Panels per tracker: 6

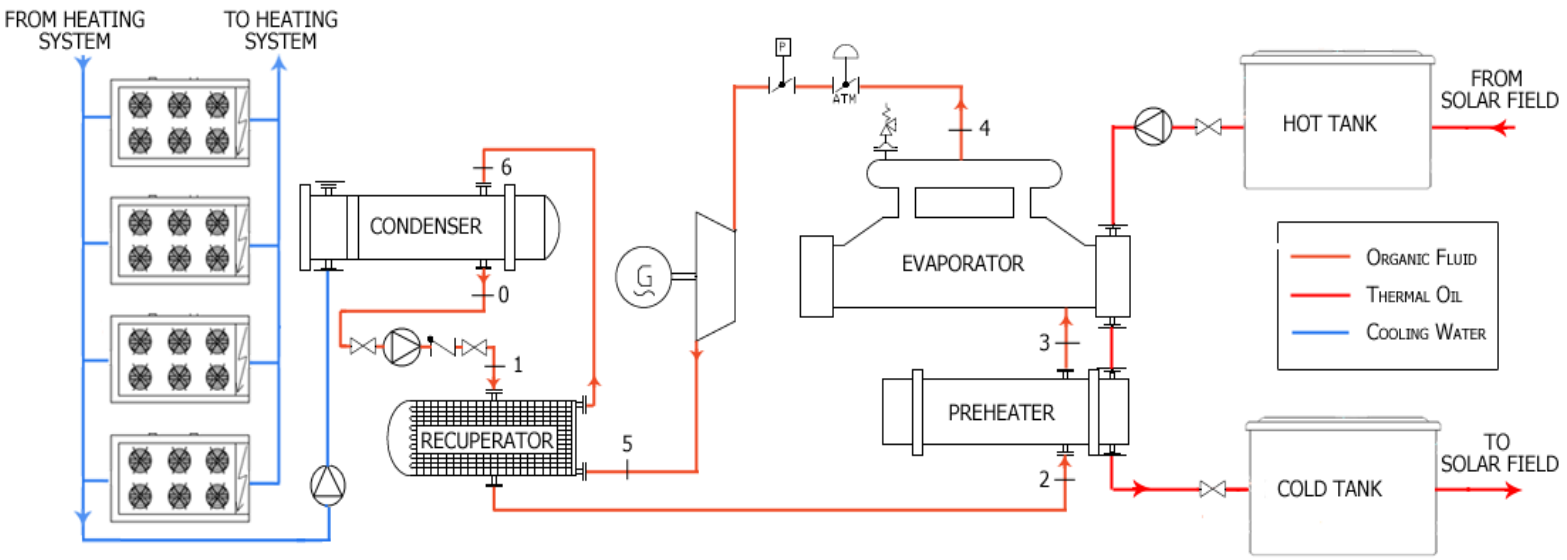
THE OTTANA SOLAR FACILITY

ORC unit:
- ORC type: Turboden 6HR Special
- input thermal power: 3100 kWt
- gross/net power output: 664/629 kWe
- gross/net efficiency %: 21.4/20.3
- turbine inlet/outlet temperature: 275/165°C
- Electric generator: 50Hz/400 V

Battery bank:
- Battery type: $NaNiCl_2$
- Numbers of batteries: 24
- Battery bank capacity: 430 kWh
- DC/DC efficiency: 94%

THE ORC UNIT

Schematic view of the ORC unit:



SUPERVISION & CONTROL SYSTEM

Main goal: ability of the overall CSP+CPV system to deliver **scheduled profiles** in accordance with the **weather forecasting**

Control logic: combination of a **one-day ahead scheduling procedure**, which defines the set-point of the CSP+CPV power production for the following day, and a **real-time control algorithm** for the power profile tracking according to actual meteorological data.

Determination of the daily ORC profile:
Trade-off between two conflicting goals:

- The maximization of the **ORC performance**, achieved by operating it as close as possible to nominal conditions for high duration periods and with a low number of ORC start-up.
- The maximization of the **matching** between **CPV and ORC power delivery periods**, exploiting the storage capacity of the CSP section to minimize the fluctuations in the CPV power production.

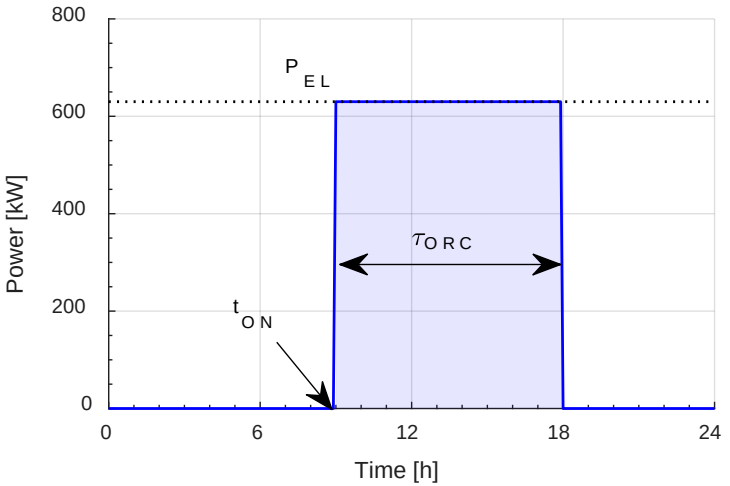
DETERMINATION OF THE DAILY PROFILE

Main Input:

- Weather forecast data (**DNI, T_{AMB}, Wind speed**) for the calculation of the expected solar field energy production (E_{SF})
- **Stored energy** in the hot tank at the end of the previous day (E_{TES})
- Expected thermal energy availability ($E_{IN} = E_{SF} + E_{TES}$)
- clearness index K: ratio between the expected E_{SF} and the corresponding E_{SF} in clear-sky conditions

Main Output:

- the ORC on/off state
- the net electrical power output P_{EL}
- the corresponding duration period τ_{ORC}
- the start-up time t_{ON}

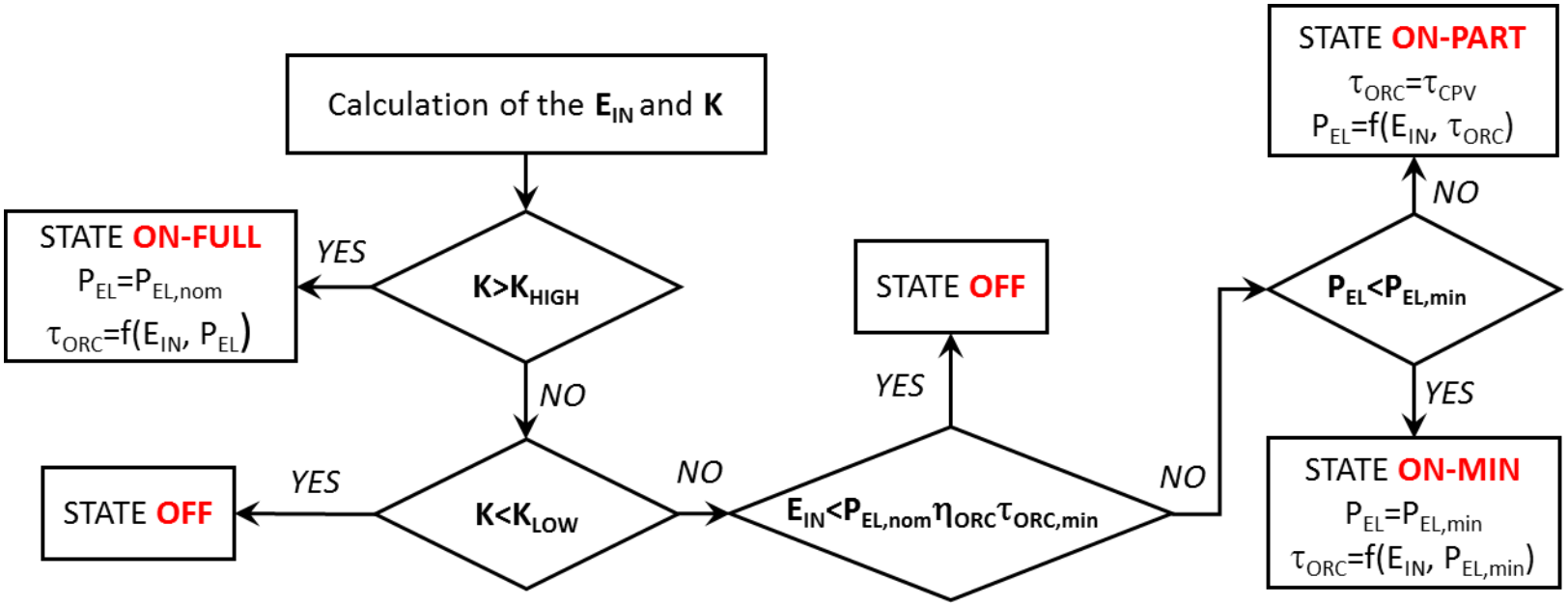


Control parameters:

1. Two clearness index threshold values (K_{HIGH} and K_{LOW})
2. minimum number of operating hours $\tau_{ORC,min}$ at nominal conditions

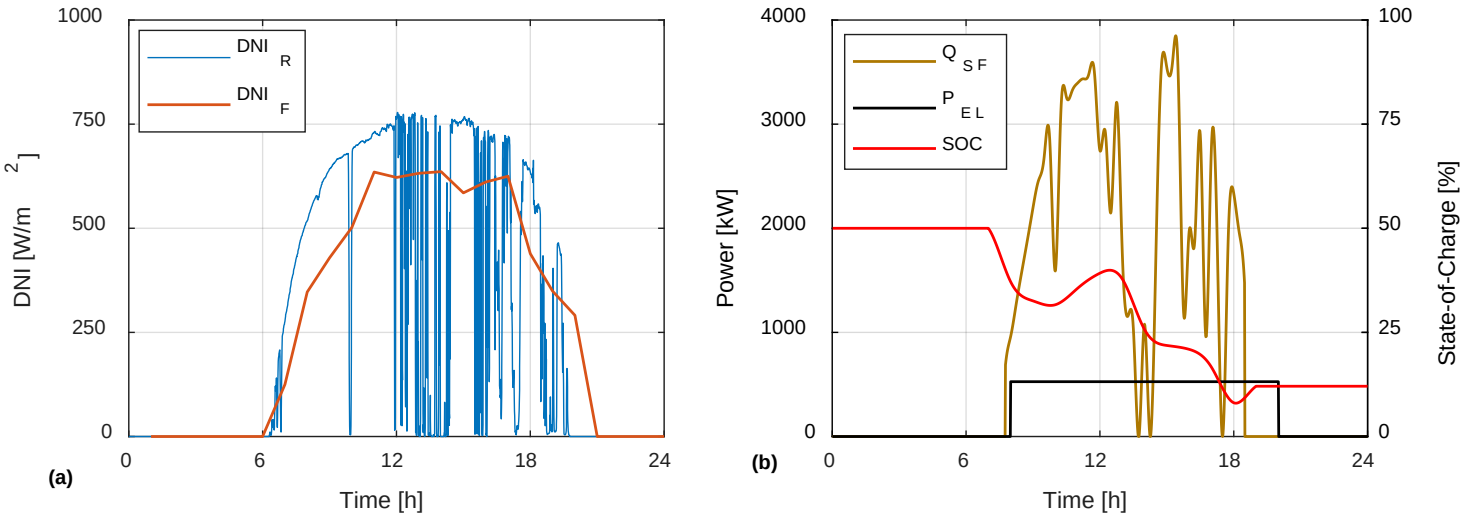
DETERMINATION OF THE DAILY PROFILE

Logic block diagram:



DAILY PERFORMANCE

Forecast and measured DNI and energy flows during commissioning test:



*STATE ON-PART**

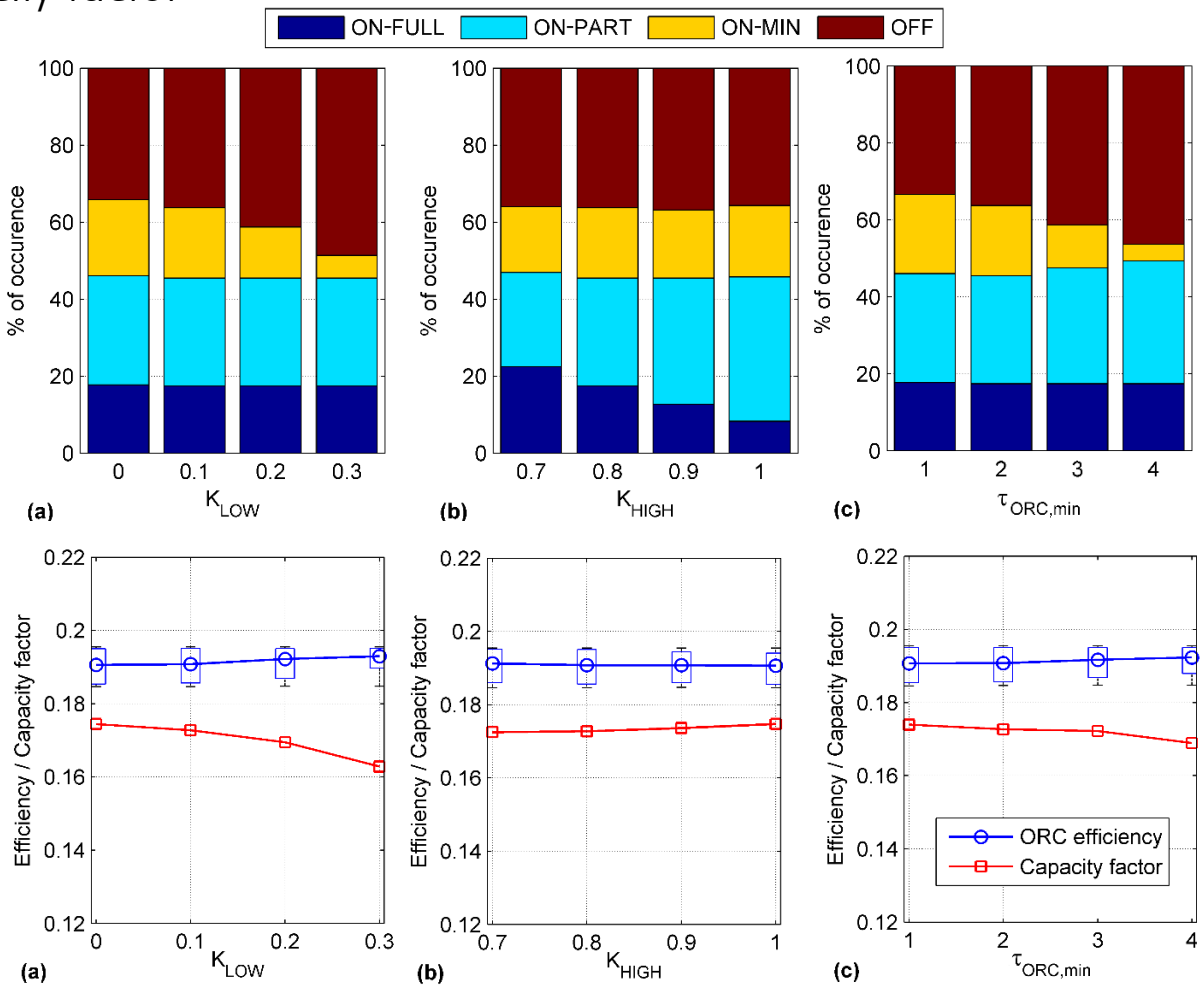
Expected annual performance:

Solar energy availability [MWht]	14650	Mean ORC efficiency [%]	19.1%
Solar field energy output [MWht]	5076	Mean ORC power level [kW]	430
Defocusing energy losses [MWht]	160	ORC running time [h/year]	2188
ORC power production [MWh]	941	Number of ORC start/stop	217

* K_{LOW}=0.1
K_{HIGH}=0.8
$\tau_{ORC,min}$=2h

ANNUAL PERFORMANCE

Influence of the K_{LOW}, K_{HIGH} and $\tau_{ORC,min}$ on the ORC state, ORC efficiency and CSP capacity factor



CONCLUSIONS

This paper was focused on the ongoing studies at the Ottana Solar Facility, a new experimental power plant located in Sardinia (Italy).
The innovative configuration of the solar facility, with the integration of a CSP plant with a CPV system, demands the development of a novel control strategy for the achievement of a semi-dispatchability of the plant.
The expected performance are then presented highlighting:

1) the fundamental role of the thermal energy storage
2) the frequent operation of the ORC turbogenerator at part load and with variable input conditions.
3) The importance of three control parameters on the ORC power profile, which affects the plant capacity factor and the turbogenerator efficiency.

THANK YOU FOR YOUR ATTENTION

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