FR ALSTOM Power Systems

CH ALSTOM (Switzerland) Ltd.

IT Politecnico di Milano
Dept. of Electronics, Information and Bioengineering

ESE Engineering
Services for Energy S.r.l.

STF Salvatore Trifone
e Figli S.p.A.

PL AGH University of Science and Technology
Dept.of Applied Computer Science

EC Systems Sp. z o.o.

DE DLR German Aerospace Center
Remote Sensing Data Center

DLR German Aerospace Center
Institute of Solar Research

University of Stuttgart.
Dept. of Life Cycle Engineering (GaBi)

SK GeoModel Solar s.r.o.

PT University of Evora
Renewable Energies Chair

ES AEMET State Agency
for Meteorology

CENER National Renewable
Energy Centre

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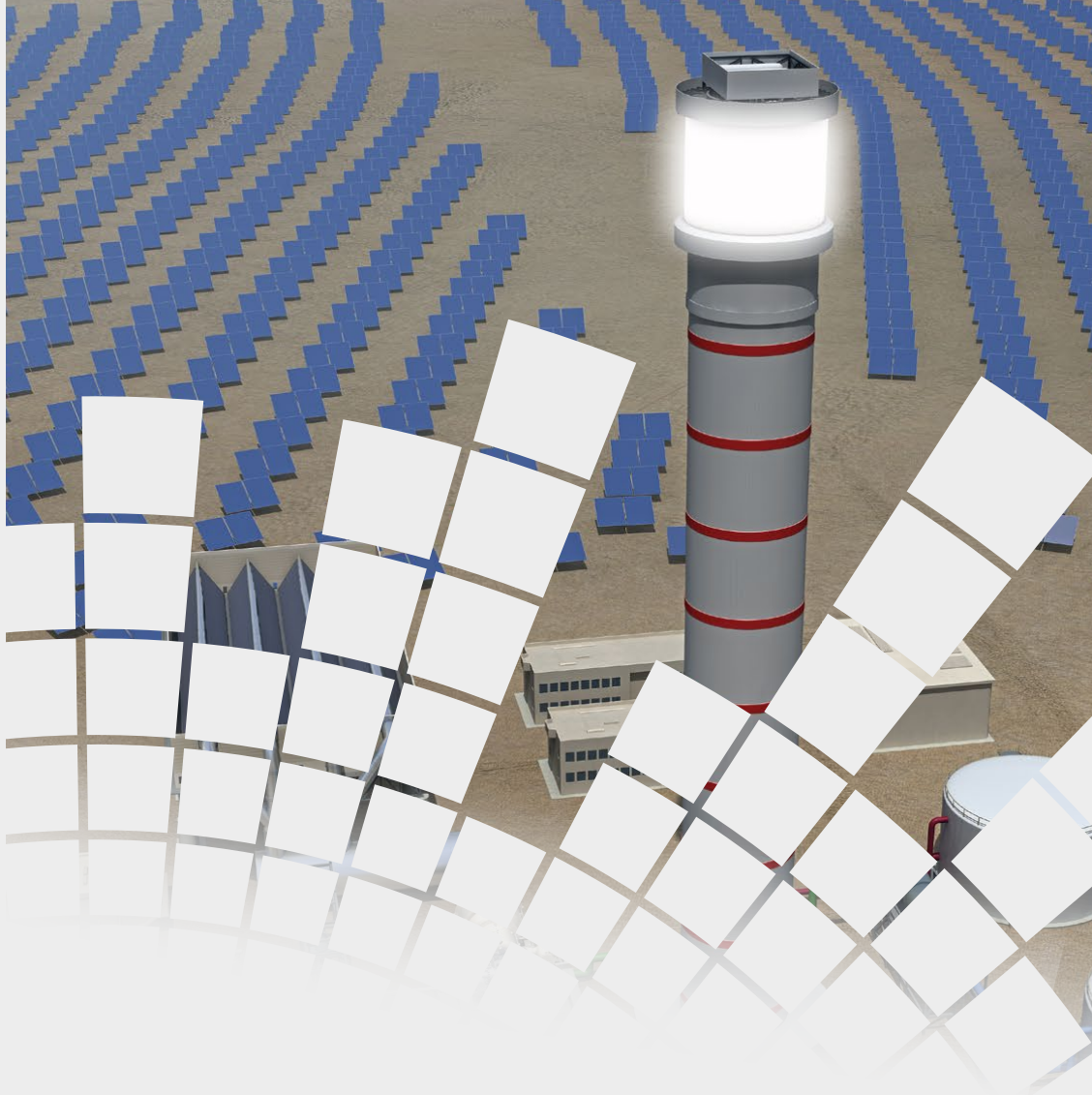
info@preflexms.eu
www.preflexms.eu

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra



PreFlexMS

PREDICTABLE&FLEXIBLE SOLAR POWER
WITH MOLTEN SALT ENERGY STORAGE

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1. BACKGROUND

In a Concentrated Solar Power Plant (CSP), a field of heliostats reflects and concentrates sunlight onto a receiver placed atop a tower. A molten salt (sodium-and potassium-nitrate) is heated up in the receiver and stored in large ground tanks. When electricity is to be produced, the hot salt is used to generate steam, which drives a steam turbine and electrical generator, supplying power to the grid.

2. STATE OF THE ART

Some large power plants (100+ MW) of this type are today in commissioning, construction or planning phase. They will be operated at constant load and produce electricity until the storage lasts into the night. They are economically viable because incentive schemes offered by regulators compensate for high initial costs and for limited operational flexibility.

3. MARKET TRENDS & NEEDS

The evolution of the CSP market will see regulators gradually phasing out subsidies. Additionally, grid operators expect from CSP stable, responsive, reliable and committed power supply, equivalent to gas power plants. Under these circumstances, CSP plant operators need flexible and reliable plants to adapt operation to market conditions and maximize their revenues.

4. MAKING CSP PREDICTABLE A

PreFlexMS will integrate improved weather and solar radiation forecast with electricity dispatch optimization. This will allow optimal operation to maximize revenues while respecting plant constraints and power supply commitments.

5. MAKING CSP FLEXIBLE B

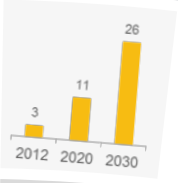
PreFlexMS will design a molten salt "once-through" steam generator (OTSG) allowing fully flexible operation with fast load changes, while bringing system simplification and cost reduction. In a new design approach, dynamic simulations will verify performance and suggest adjustments early in the development.

6. DEMONSTRATION C

CSP plants require large up-front capital expenditures, which make investors wary of unproven technologies. To guarantee market uptake, PreFlexMS will build a pilot OTSG with integrated forecast and dispatch optimizer. The demo plant will be hosted at the Evora Molten Salt Platform in Portugal.

7. BUDGET

PreFlexMS is investing more than 18 M€ over 3 years (2015-2018) to develop technologies that will make CSP plants predictable and flexible. The value of the pilot installation in Portugal will exceed 7 M€.



8. IMPACT

CSP will reach 11 GW installed capacity by 2020 and 26 GW by 2030 *, with large growth in developing markets, where grid constraints and market liberalization will play a role. PreFlexMS will make technologies for predictability and flexibility ready for the market and put European industry in the position to compete worldwide.

*IEA, World Energy Outlook 2014, "Current policy" scenario

A Weather forecasting & Dispatch optimization

- **Where technology stands**
  - Limited geographical availability
  - No reliable DNI forecast
- **PreFlexMS**
  - Extension of geographical reach
  - Improved accuracy of local DNI prediction
  - Probabilistic forecast
  - Specification of data streams and equipment set-up for CSP

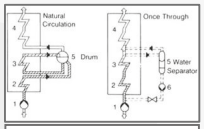
Real-time forecasting for integration in dispatch optimization

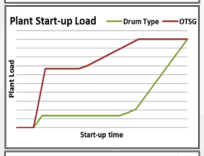
Real-time optimization under forecast uncertainty

- **Where technology stands**
  - Used for scheduling of hydro plants
  - Only concepts proposed for CSP so far
- **PreFlexMS**
  - Maximize revenues regardless of uncertainties and perturbations
  - Model re-tuning by machine learning, to reflect real plant performance

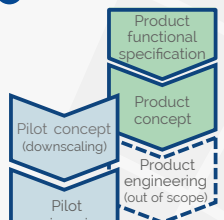
B Once-through steam generator

- Best for fast load changes
- Potential for cost reduction
- **Where technology stands**
  - Drum-type standard in solar but no flexibility
  - OTSG never applied in solar
- **PreFlexMS**
  - OTSG design & integration for CSP
  - Innovative design methodology





C Product demonstration in real-life conditions



- Down-scaling of 100+ MWe-class once-through steam generator to a 5 MWt pilot
- Real-life implementation of meteo-data streams, dispatch optimization and optimum control
- Proof of concept, evaluation, benchmarking