Next-CSP

High Temperature Concentrated Solar Thermal Power Plant with Particle Receiver and Direct Thermal Storage

European funded project - Grant Agreement number 727762

Deliverable D7.2

WP7 – Preliminary Design of the Future Utility-Scale Commercial Plant

Deliverable D7.2 – Report on scaling-up from pilot plant to commercial plant Risk analysis

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Foreword

This report (Deliverable D7.2) describes the Risk Analysis of the Scaling-up of the concept developed in Next-CSP, from demonstration unit to utility-scale power plant (about 150 MWe). The report was written by EDF with significant help from EPPT for all issues involving particles; CNRS, IMDEA, KUL and SBP also contributed by attending meetings and provided advice and corrections in their respective fields of expertise.

The best-suited method (namely, the FMEA or Failure Modes and Effects Analysis) is briefly described, as well as other methods that were partially used. The future scaled-up power plant is then broken down into subsystems and the FMEA is applied to each subsystem. Safety, Health and Environment (SHE) issues are also analyzed. For each subsystem and SHE, all significant risks (also referred to in this document as potential failure modes) are listed; for each risk, mitigation measures are sought, then both its occurrence (i.e. likelihood) and impact are rated according to a 5-step scale. Eventually, a 5x5 risk assessment matrix summarizes the results of this analysis.

In conclusion:

- The top-priority mitigation measures (corresponding to the failure modes with the highest impact and/or occurrence) are listed;
- Considering that said mitigation measures are implemented, an assessment of the overall risk affecting the scaling-up of the Next-CSP concept at utility scale is conducted.

1 Objective of the study

As stated in the Grant Agreement [1], the Work Package 7 of the Next-CSP project (project N. 727762 [1]) involves several issues.

The general design of the plant was outlined in Deliverable D7.1 issued In November 2018 [2]. The necessity of performing a Risk Analysis of the scaling-up of the Next-CSP pilot plant to utility scale is obvious, at least for the following reasons:

- Several design characteristics of the commercial plant are absent in the pilot plant:
    - Multi-tower architecture (8 towers in D7.1, but likely to be reduced to about 6 towers);
    - Horizontal conveying of the hot particles totaling several kilometers;
    - Massive thermal storage of hot particles at ground level;
        - Double reheat gas turbine as opposed to the no-reheat gas turbine of the pilot plant;
    - No supplementary firing (i.e. fuel combustion prior to the expansion turbine) in the commercial plant. Although a design simplification, this corresponds to a much higher air temperature allowed by the external heat input provided by the particles to the working air of the gas turbine.
- Due to the multi-tower architecture, the scale-up ratio for the solar receiver is about 17 (from a thermal power of 3.0 MW_{th} to about 50 MW_{th}).
- Although crucial for a commercial plant, component lifetime will not be addressed by the test performed on the pilot plant.

The risks attached to the scale-up (which, by nature, are not treated by the pilot plant) will not materialize before utility-scale plants start to be erected. Should Next-CSP exclude any previous analysis, risk analysis and mitigation would be assigned to individual partners or subcontractors during the erection, then commissioning, then operation of the first scaled-up plants. Experience feedback shows that this is not an efficient way of properly identifying the risks, let alone assessing and mitigating them. The risk analysis must be performed at plant scale and beforehand. This is why including a Risk Analysis in the Next-CSP project (and, specifically, in Work package 7 dedicated to the scale-up at utility scale) is deemed to be mandatory.

The objectives of this document are to:

- Identify all the technological risks induced by the scale-up of the concept from pilot plant to utility-scale commercial plant (to be built around 2030);
- Rather than quantify them (see the reasons below), rank them by decreasing priority according to the relevant criterion or set of criteria;
- Propose strategies to mitigate them whenever possible.

A screening of the existing risk analysis methods allowed us to select the most relevant ones in order to meet the abovementioned objectives. Among the four methods chosen, two (FMEA and Matrix Analysis) were our main tools whilst the remaining two (SWIFT and DELPHI) were only used as additional support.

2 Scope of the study

Any risk that affects the whole CSP industry will in turn threaten the scaling-up of the Next-CSP concept. Examples would be a sharp decrease of the cost and the environmental footprint of electrochemical storage (i.e. batteries), the upscaled proof of thermochemical storage, the commercial development of high temperature encapsulated PCM, etc. However, we decided to

exclude this category of risks from our study and to focus on the risks that are specific to the scaling-up of the Next-CSP concept.

The final purpose of the Next-CSP concept is to build scaled-up commercial plants whose LCOE is lower than that of a molten salt tower that is the current benchmark and is likely to remain so during the next decade. As shown in the WP7 Milestone delivered in April 2019 [3], this is not a foregone conclusion, even without considering any unexpected LCOE increase. Therefore, the future of the Next-CSP concept is threatened by:

- Issues that may prevent project developers or manufacturers from successfully building several scaled-up plants at commercial scale (i. and ii. below);
- Any significant and unexpected economic penalty, corresponding eventually to an increased LCOE compared to that contemplated in the WP7 Milestone (iii. to vi. below).

The potential risks that may affect a scaled-up Next-CSP plant belong to at least one of those categories:

i. Technological unfeasibility to build commercial plants if e.g. at least one technological hurdle was underestimated and appears to be a non-starter;

ii. Unfeasibility to build commercial plants because no manufacturer accepts to mass-produce a component or system that is specific to the Next-CSP concept;

iii. Reliability issues (for example, of the particle conveying system) that have an impact on operating costs and/or availability and efficiency (i.e. on power production);

iv. Lower than predicted performances (example: thermal losses during particle conveying remain too high despite our efforts to mitigate them);

v. Higher than predicted investment and/or operating costs (for reasons other than iii. or iv. above);

vi. Safety and/or environmental issues that prove trickier than predicted (therefore requiring costly mitigating means).

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