PreFlexMS Report Summary
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Periodic Reporting for period 1 - PreFlexMS (Predictable Flexible Molten Salts Solar Power Plant)

Reporting period: 2015-06-01 to 2016-11-30

Summary of the context and overall objectives of the project

The PreFlexMS project aims to demonstrate relevant hardware and software innovations and applications that would raise the competitiveness of the CSP plants of the future, by making them predictable and flexible in terms of dispatch requirements such that they can compete head-to-head as an energy source against any comparable large scale fossil-fuel plants like combined cycle gas turbines without special economic incentives. The hardware elements of the project involve demonstrating a molten salt once-through-steam generator (OTSG) which through its quick ramps and load following ability is able to provide dependable balancing power to various types of grid and energy market conditions. On the other hand the software elements combine advanced CSP specific weather forecasting with dispatch optimisation and machine learning algorithms to ensure predictable and economically optimised plant operation under a variety of weather conditions. These elements would be demonstrated together at an industrial scale pilot at a solar facility in Evora, PT.

The following are specific objectives of the project
1. Improve state-of-art in molten salt CSP plant flexibility by designing and demonstrating the advantages of using a once-through-steam-generator compared to drum type steam generator

2. Extend reliable Direct Normal Irradiation (DNI) forecasting for the promising markets of the future like MENA, South Africa and South America. Refine and update models and methods used to provide such services and ensure high quality forecasting ability to ensure dispatch predictability. Provide the software architecture and capability to do so.

3. Design and demonstrate dispatch optimisation software that can utilise the developed forecasting, plant and machine learning models to maximise economic payback in various market scenarios by flexibly scheduling storage enabled CSP plants.
   a. Evaluate techno-economic figures of merit like cost of electricity and net present value
   b. Assess the data collection, transmission, management, computation and actuation related to the weather forecast and dispatch optimisation in an industrially relevant operational environment
   c. Perform a life-cycle assessment including the benefits of all the novel components of the CSP plant

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

Electricity price profile projections were made based on today's energy mix and the countries announced renewable energy strategy to estimate the pricing regime in the future. Certain countries are expected to have strongly fluctuating hour-to-hour
pricing which call for added flexibility like South Africa, India and Saudi Arabia while others like Chile, Morocco will require flexible operations due to the grid operators requirements.

Reference design of the full power block based on a once through steam generator is made for a full scale CSP plant. Important functional features for flexibility are calculated using high-resolution dynamic modelling. It is expected that the once-through steam generator would be quicker, more responsive and more economical to operate with respect to total cost-of-ownership compared to a drum type steam generator.

Weather forecasting infrastructure and digital interfaces with demonstration software architecture have been defined. Novel methods for DNI forecasting and impact of aerosols have been investigated and the validation sites relevant for different CSP use cases have been selected. A virtual power plant model for the CSP plant which incorporates the static and dynamic modelling of the various components has been achieved. This will be used to test the dispatch optimiser as well as the machine learning algorithms. The entire software architecture for collection, management, computation and actuation is also designed and will now be built. The models to be used for weather forecasting and their specifications for optimiser interface have been defined.

Based on the performance model, it appears that two strategies for dispatch optimisation would be developed further, a dynamic programming based optimiser and a heuristic approach for quicker speed and performance. Multiple machine learning algorithm strategies have already been assessed and the most promising ones are to be tested on the software models.

With respect to the demonstration hardware, the water steam skid and other auxiliary balance of plant equipment has been designed and is under procurement to allow OTSG to operate in industrially relevant environment. The various engineering studies to safely construct and operate the demonstration have been performed and now the procurement activities are ongoing. The engineering design of the water steam skid, interconnecting piping and OTSG pilot design is also completed. Procurement and construction activities are to follow at the site.

A specialised life-cycle assessment tool is used with extensive data collection to obtain important LCA measures. Tool buildup and data collection is ongoing within this task.

**Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)**

The innovation potential is highest for the weather forecasting and software elements since CSP plants of today operate with fairly simple and stable control algorithms in order to provide baseload power. Weather forecasting integration has so far not been done for the sake of dispatch optimisation in any commercially operating plant. OTSG has also never been used in a CSP plant.

The main deliverables on the hardware side will be the design experience, lessons learnt from actual operation, a reference design for the OTSG and associated control logic. On the software side the new models and evaluation methods to improve weather forecasting for CSP applications are expected to be available. Finally, the analysis of the project results will be used to update the economic value and competitive advantage of a CSP plant with the innovative features. Ultimately, this project will enable the consortium partners to offer the next generation of full scale CSP plants by reducing technology risk.

The expected socio-economic impacts can be summarised as follows.

Replicability: It is expected that the OTSG hardware engineering can be replicated by the relevant consortium partners and reduce market entry barriers to others.

Socio-economics: On one hand, European technology providers benefit from increased export markets, on the other hand, sunny developing countries gain new technological skills and higher low-carbon growth through large scale project construction.

Environment: Increased predictability and flexibility of CSP plants, allows them to compete effectively without any special considerations against fossil fired plants. The primary impact is to reduce carbon emissions from power generation while still maintaining grid integrity. This reduces the need for polluting fossil fired back up even in countries with high renewable penetration.
Market Transformation and Policy: This project would influence new policies that enable creation of remunerative markets for integrated storage with renewable electricity as well as set new standards to describe and overcome uncertainty of weather when investors compute the risk profile for a CSP project.

Related information