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Dish-Stirling Development

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ABSTRACT

Stirling Energy Systems (SES) is pursuing an aggressive deployment of 25kW dish-Stirling systems for bulk power generation. Their hardware is based on the tried-and-true McDonnell Douglas design, with refinements for reducing manufacturing costs. SES is working closely with Sandia National Laboratories' engineering team in order to maximize the possibility of success.

This year, SES deployed a first prototype of the upgraded system at Sandia. SES has a significant engineering presence at Sandia in order to enhance technology transfer and support. Sandia engineers provided critical development support to resolve structural and optical issues with the prototype, resulting in successful operation within SES's aggressive schedule.

The prototype success led to the start of manufacture of five more units, also to be installed at Sandia. These will form a "mini power plant", scheduled for operation in 2005, for demonstration, exploration of field operation issues, and reliability improvement.

1. Objectives

The DOE dish-Stirling program is working closely with industry to improve system performance and reliability, and to support deployment by industry in the near term, both explicit goals of the Multi-Year Program Plan section 4.2.5.3. This year, our primary goal was to install, test, and begin to baseline the performance (reliability, availability, and efficiency) of the SES 25kW dish-Stirling system. The system is a derivative of the successful McDonnell Douglas system, redesigned to improve cost. SES's objective is to put this system into production as early as 2007, with a target market of bulk power production in the southwest United States. This corporate goal drives the DOE goal of determining the baseline performance of the system, so that follow-on work can address performance improvement.

2. Technical Approach

SES plans to achieve cost reduction by rapidly moving to high production rates in support of bulk power production. This has the advantage of lower cost through production automation early in the product design cycle, and lower O&M cost via location resource consolidation, when compared to smaller prototype installations spread out at many locations.

We proposed and implemented a very close cooperation between the Sandia and SES teams, co-locating the SES engineering team at Sandia's National Solar Thermal Test Facility. This provides direct access to technology transfer and expertise, and allows the engineers daily hands-on access to the dish systems. This is critical to accelerating the development and deployment path, as well as rapidly training new solar engineers.

Early in the year, we installed an SES-owned McDonnell Douglas system as a development platform at Sandia. We installed WG Associates controls (now a SES division), as developed on Sandia's 10kW Advanced Dish Development Systems [1]. These controls allowed us to rapidly move to unattended automated operation, greatly increasing the hours of system operation. We used this prototype to catalog issues, verify performance, and test new hardware approaches. This dish system was designated "serial 00"

SES then installed an SES-built dish at Sandia, implementing reduced-cost approaches to fabrication and design. This system serves as a prototype for the SES commercial system, and after significant cooperative re-work, the low-cost system performance was improved to match or exceed the older system. This system incorporated drive motor, mirror facet, and mechanical joint design improvements over the McDonnell Douglas system, and represents the first system fabricated by SES. The system is used to explore potential reliability and cost reduction issues. This system is designated "serial 0"

Finally, SES is pursuing an aggressive schedule to install five more dishes at Sandia by Christmas 2004, creating a six-dish "mini power plant" to be used to rapidly address field control, operations, and maintenance issues. All of the dish system hardware is funded through SES investor financing, while Sandia provides in-kind engineering support, technology transfer, training, and facilities.

3. Results and Accomplishments

The serial 00 system was operated at Sandia for 1045 hours, primarily unattended. We developed effective closed-loop tracking algorithms to optimize system performance continually by balancing the cylinder temperatures. We cataloged the problem areas on this system, and used this to guide development changes on the SES design where feasible. A major change eliminated the troublesome "fast slew system", replacing the drive motors with faster DC drives and providing secondary failsafe with azimuth slewing. We also explored possible field alignment tools and schemes for the production dishes. The system remains available for testing proposed engine modifications. Later operation, however, has centered on the new serial 0 system.

The serial 0 system was designed and fabricated using lower-cost fastening systems and employs Panaltec structural facets [1]. These facets have a typical RMS slope error of 0.6 to 0.8 mR, as measured by the National Renewable Energy Labs' (NREL's) VSHOT system [2]. Combined with the low-iron-glass reflective surface, the performance of the new dish should be exceptional.

The changes driven by cost reduction led to a dish structure that was too flexible for safe operation, as the peak flux in the vicinity of the receiver varied with sun elevation, with a maximum over 250W/cm². The design flux in this area is around 90W/cm². Through an aggressive measurement and remediation program, we identified and resolved all of the structural issues. We used NREL's flux mapping system to verify that the flux patterns are now consistent with the system design specifications. All of the system improvements were designed with cost in mind, and were applied to the design of the proposed five-unit build.

System operation with an engine began August 3, and we have accrued 300 hours of operation. We have continued to catalog faults, and have developed remediation plans to address each fault category. We are beginning to map the baseline system performance with calibrated instrumentation.

Finally, based on the upgrades to serial 0, we completed a drawing package and began fabrication of the next five units. These units will be installed at Sandia, with the goal of an operational six-dish mini-power-plant by December 23. We have begun extensive analytical modeling of the dish structure, in order to feed back to the design process to reduce the costs in the next-generation design. The output of the analytical model has been compared and calibrated to structural deflections measured as we mechanically loaded a half-dish mock-up at the steel fabricator in Phoenix. Most of the deflections were in agreement within 10%. The model is also used to validate the design changes that were empirically introduced on serial 0.

We are designing a substantial software upgrade to the dish controller to support the mini power plant operation. The key change involves upgrading the communications so the controls can be integrated into a field-wide SCADA system with a multi-drop serial network.

SES is developing the in-house capability to fabricate the Kockums-design engine. Five new engines are in fabrication at Sandia and subcontract suppliers, and these will be applied to the mini power plant. The engine support structure and radiator assembly has been substantially re-designed to reduce cost, provide superior access to the engine, and use off-the-shelf components where possible.

The foundations and conduits have been installed for the additional systems. System installation will begin with pedestal and electronics in October, and dish assembly and alignment in November and December. This rapid deployment of five dishes is aggressive, and involves manpower from key production suppliers.

SES is also actively planning and pursuing opportunities for additional multi-unit prototype installations in the next year or two, as well as developing suppliers and customers for large-scale production and deployment. SES is continuing to grow its workforce at Sandia, with about 10 engineers on site already. This team, along with Sandia, is dedicated to meeting the immediate mini-power plant deadline, while simultaneously preparing for commercial production. The daily access by engineers to prototype hardware is considered critical to the success of the rapid development cycle. Additional tools for laboratory testing are being implemented, and will speed development and qualification of new hardware solutions on the engine package.

Sandia has instituted record keeping and data acquisition approaches that are key disciplines to determining root causes of problems, characterizing performance, and improving the systems. We are starting to compile the key data to establish baseline performance of the system as well as the mini power plant.

4. Conclusions

SES and Sandia National Laboratories have successfully transitioned from operating old McDonnell Douglas dish systems to deploying and operating an SES-built system with modern manufacturing techniques, updated controls, and a lower-cost approach to fabrication. Key suppliers have been involved in the design, fabrication, and deployment of the first system. SES is on track to deliver, install, and operate a six-dish mini power plant by Christmas 2004. An aggressive program of identifying and cataloging problems and developing and implementing solutions has made operation of the new system a success. We have started to characterize the system performance in terms of power, availability, and reliability.

The SES approach to marketing, development, and deployment of many dish-Stirling systems in centralized power plants is unique and aggressive. The first dish deployed at Sandia, as well as the upcoming mini power plant, are key steps in developing the technology and expertise needed for this undertaking. The partnership between Sandia and SES not only addressed a congressional spending line item, but did so in a way that maximizes the benefit to SES while continuing to leverage the expertise developed at the Laboratories.

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