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COOLIDGE SOLAR POWERED IRRIGATION PUMPING PROJECT

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ABSTRACT

Construction of a 150 KW solar thermal-electric power plant on an irrigated farm near Coolidge was completed in autumn, 1979. The plant, designed by Acurex Corp., includes over 2100 m^2 of Acurex made parabolic trough type collectors and an organic Rankine cycle turbine engine built by Sundstrand Corp. The plant is interconnected with the electrical utility grid. The installation is being operated by the University of Arizona with Sandia Laboratories direction. Operation is providing an evaluation of equipment performance and operating and maintenance requirements as well as the desirability of an on-farm location.

BACKGROUND

Approximately 13 percent of the energy used on U.S. farms is used for pumping to irrigate about 20 million hectares (50 million acres) or 13 percent of the total cropland (5,9). About 85 percent of the irrigated cropland is located in 17 western states. On farms with deep subsurface water sources, 70-90 percent of the crop production energy may be used for pumping (8). The magnitude of irrigation energy requirements, potential natural gas shortages and greatly increased energy costs motivated a request to examine the use of solar energy to drive irrigation pumps by Arizona farmers after the oil embargo of 1974.

A University of Arizona feasibility study in 1975-76 listed a number of engineering and economic factors to be considered and conditions to be met for successful marketing and use of solar powered pumping plants (7). These included development of lower cost solar devices, improved energy use management and availability of capital at a modest price. During the past three years, four known solar power plants have been constructed to evaluate the use of solar energy to drive irrigation pumps. The first three units began operation in 1977; construction of the fourth was completed in autumn, 1979.

Photovoltaic cells are used to provide up to 25 kilowatts (KW) of electrical energy to drive irrigation pumps at the University of Nebraska farm near Meade (10). Parabolic trough type solar collectors and Rankine cycle turbine engines are the principal components of the other earlier systems (1,3). The two plants, a 50 KW installation located on a farm near Gila Bend, Arizona and a 25 KW plant on a Willard, New Mexico farm, are directly coupled to pumps with electric motor backups. The Willard installation includes considerable thermal energy storage capacity for nighttime operation while the Gila Bend plant has none.

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COOLIDGE PLANT

The fourth experiment encompasses design, construction, operation, and evaluation of a 150 KW solar power plant. Plant size was selected to meet the energy requirements of deep well pumping to provide irrigation water for a quarter section or 65 hectares (160 acres) of Arizona cropland. The plant generates electricity since existing pumps were electrically driven and the power can be readily used in other applications.

The 150 KW plant is located on the Dalton Cole farm southwest of Coolidge in central Arizona. The cooperator was selected from among a group of volunteer farmers by a governor-appointed committee. An important factor in site selection was cooperation of the local utility company. Backup energy is required to assure pump operation; full utilization of solar plant output is economically desirable. Electric District Number Two, the local utility company, is supplying or purchasing energy as required.

The Arizona experiment is funded by the U.S. Department of Energy and technically supervised by Sandia Laboratories. Additional funding and technical support have been furnished by the Arizona Solar Energy Commission and the University of Arizona, respectively. In the first phase of the project conducted in 1977, competing conceptual designs were developed by three firms: Honeywell, Black and Veatch, and Acurex. Honeywell proposed use of several large parabolic dish collectors. A Brayton cycle turbine engine and electrical generator set were to be mounted adjacent to each collector receiver. Black and Veatch proposed a field of heliostats or individually tracking reflectors, central receiver type collector, and Rankine cycle engine. Acurex proposed use of a field of single axis tracking, parabolic trough type collectors and Rankine cycle turbine engine.

The Acurex Corporation concept was selected for design and construction in late 1977, appearing to have the fewest technical unknowns and be most economical. The solar power plant plans consisted of collector, energy storage and energy conversion sub-systems, Figure 1.

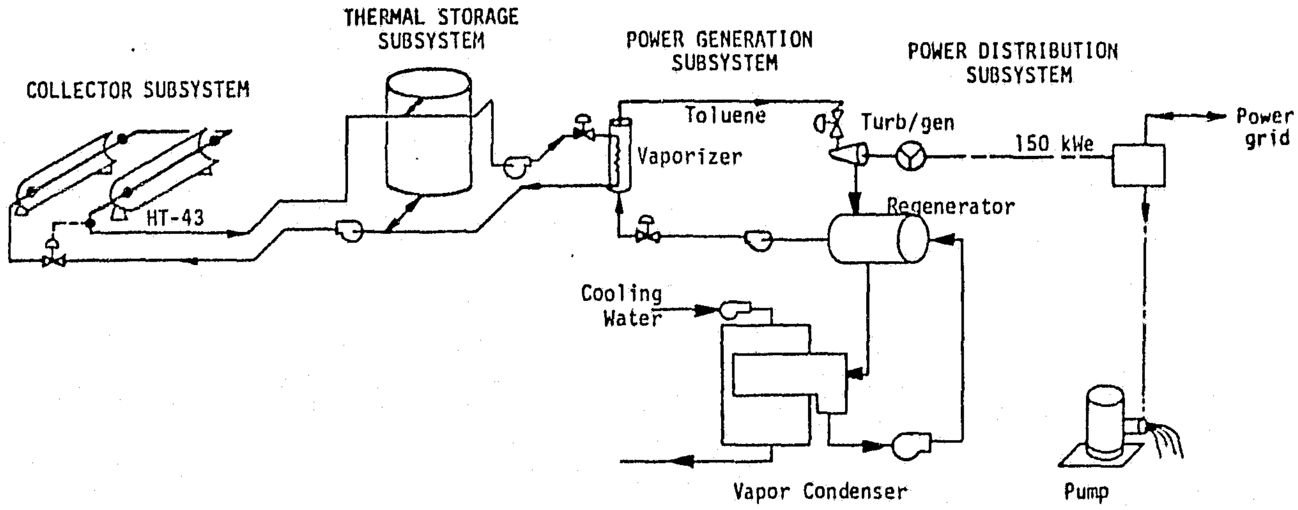

FIGURE 1. Schematic diagram of the 150 KWe solar powered pumping facility (2).

The collectors, 1.83m wide by 3.05m long (6 feet by 10 feet), have reflective parabolic surfaces of aluminum (Coilzak) and concentration ratio of about 36 to 1. Collector receiver tube is coated with a selective black chrome surface and surrounded by a pyrex tube. The collectors, manufactured by Acurex, are arranged in a series of north-south oriented rows. Solar collector area is greater than 2100 square meters (23,000 square feet). An addition is being planned which will nearly double the collector area.

A heat transfer oil, Caloria HT43, is being used as the collector fluid. This oil remains stable and in fluid state at the 288°C (550°F) temperature to which it will be heated permitting low pressure flow. Energy storage is a 113 cubic meter (30,000 gallon) tank of hot oil. Initial collector area permits only daytime operation. The planned collector addition will permit about 20 hours of operation on a sunny June day.

Energy conversion is accomplished by a Rankine cycle turbine engine through expansion of the organic fluid toluene. The engine, made by Sundstrand Corporation, is a scaled down version of one developed for other relatively low temperature applications such as conversion of power plant waste heat. Net engine efficiency is expected to be 17 percent; overall system energy collection and conversion efficiency is expected to average seven percent annually.

EVALUATION

The Arizona experiment is providing an evaluation of a relatively small sized power plant located on a farm in Arizona and interconnected with the electrical utility company grid. The economies of scale for solar power plants are not well known; different designs might be more appropriate with different sized plants. This experiment is evaluating a design using distributed, parabolic trough type, concentrating solar collectors and Rankine cycle, turbine engine to generate 150 KW of electrical energy.

Location on a farm in central Arizona provides an evaluation in that environment; some of the characteristics being sunny,hot, and dusty. Solar plant operating and maintenance requirements, competing land uses and energy use management all affect the desirability of an on-farm location. Land is available in agricultural areas in central Arizona. However, operation and maintenance of a power plant is a new and additional farm task. Minimum attention was a solar plant design objective; amount and type of attention will be determined.

Since solar power plants are capital intensive, complete utilization of output is desirable to minimize energy production costs. More complete solar powered pumping plant utilization may be obtained through energy or water storage or use of alternative energy sources during peak demand periods (7,11). Crop residues and animal wastes are two potential energy sources. However, pumping energy costs will not necessarily be reduced by the use of other energy sources or storage. Interconnection with the electrical utility system could require less management and perhaps be most cost effective. Mutually beneficial operation might involve purchase of off-peak supplemental energy from the utility company and controlled period generation and sale of energy to the utility.

The backup and utilization problem has been resolved in the Arizona experiment since the local utility company is providing energy when solar plant output is insufficient and purchasing energy not needed on the farm. Plant output and farm use will be recorded and conservation and load shifting measures will be examined to determine methods for improved matching of energy supply and demand.

The University of Arizona is operating the Coolidge solar plant with technical assistance from Sandia Laboratories and the manufacturers. This operation is evaluating new solar power plant components and determining operating and maintenance requirements. A number of experiments also are being conducted to evaluate solar collector, thermal storage and turbine generator operation. Performance and operating and maintenance requirements data will be used to suggest methods to improve performance, reduce servicing and increase reliability. To date, the solar plant has been operated almost daily for over two months and storage tank thermocline stability and winter solstice energy collection tests have been conducted.

Solar power plant production cost estimates are high, tentative and variable-from less than $3,000 to over $10,000 per kilowatt of output (2,4). Preliminary analyses have indicated some necessary conditions for cost competitiveness with alternative energy sources (6). These include low capital and operating costs and high utilization. This experiment will provide additional information on future capital and operating costs and plant utilization. Economic analyses will be updated as information becomes available.

CONCLUSIONS

The Arizona 150 KW solar powered pumping experiment is providing an evaluation of a medium sized solar power plant using distributed collectors and much new technology. The application appears appropriate since irrigation demand reaches a peak during the period of maximum insolation, a farm can provide a good environment for solar devices including adequate land area, and farmers are seeking alternative energy sources.

The experiment is expected to provide information on design, operation, and maintenance which will lead to equipment improvements. The experiment also is expected to indicate the practicality of locating a solar power plant on a farm and provide comparative cost data. Thus, the experiment is an important step in the development of solar power plants.

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