SOLAR POWERED IRRIGATION PUMPING EXPERIMENT

by

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INTRODUCTION

More than 50 million acres or about 13 percent of all farmland receives some irrigation (Sloggett, 1977). Approximately 85 percent of the irrigated land is concentrated in 17 western states. Underground aquifers provide water for about two-thirds of the irrigated area.

Irrigation pumping accounts for approximately 13 percent of the energy used on-farm in the U.S. (ERS/USDA, 1977). However, on farms with deep subsurface water sources, 70-90 percent of crop production energy may be used for pumping water (Larson and Fangmeier, 1978).

Nationally, electricity drives pumps serving about 45 percent of the irrigated farmland. Natural gas is used to supply water to 30 percent of the area. Diesel fuel and LP gas meet most of the remaining pumping energy requirements.

Pumping energy costs vary with energy costs, pumping efficiency, water depth and delivery pressure. In Arizona, deep well pumping energy costs range from less than $20 to over $60 per acre foot of water (Hathorn, 1978).

The magnitude of the irrigation energy requirement, potential natural gas shortages, and increased pumping energy costs have led to an examination of solar energy (Larson, et al, 1978a). In the past three years in the U.S., four known experiments have been initiated to evaluate the use of solar powered pumping plants on farms.

Photovoltaic cells are used to provide up to 25 KW of electricity for pumping in an experiment at Meade, Nebraska (Twersky and Fischback, 1978). Rankine cycle turbine engines and parabolic trough type solar collectors are principal components of the three solar thermal systems. Two of the installations, a 50 KW unit located near Gila Bend, Arizona and a 25 KW plant located near Willard, New Mexico, are directly coupled to pumps and have electrical motor backups. However, only the Willard installation includes energy storage. This paper describes the fourth experiment, a 150 KW solar thermal power plant presently being constructed on a farm near Coolidge, Arizona.

OBJECTIVES

Objectives of the Arizona solar powered pumping experiment were design, construction, and evaluation of a solar thermal power plant to meet the deep well pumping requirements of Arizona farmers. The plant size, 150 KW, was selected to meet the peak pumping energy requirements for irrigation of a quarter section or 160 acres. The plant will generate electricity, the principal pumping energy form in Arizona.

Unattended or minimally attended operation on an actual farm was another objective. Potential test sites were evaluated and a farm located six miles southwest of Coolidge, Arizona, and owned and operated by Dalton Cole was selected. The University of Arizona will assist by monitoring solar plant operation to determine operational and maintenance requirements.

Full utilization of solar plant output is economically desirable; backup energy is required to assure continuous pump operation. The local utility company, Electric District Number Two, agreed to participate in the experiment and will supply or purchase energy as required.

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DESIGN

In phase one of the experiment, competing conceptual designs were developed to meet specific operational requirements. The requirements included cost effectiveness, use of currently existing hardware and technology, 20 year lifetime, operation in the Arizona environment and 150 KW electrical output when solar insolation is greater than 600 watts per square meter.

The U.S. Department of Energy funded and Sandia Laboratories supervised development of alternative concepts by three companies: Honeywell, Black and Veatch, and Acurex Corporation. Honeywell proposed use of a series of parabolic, two-axis tracking dishes to concentrate solar energy at the focal point where Brayton cycle turbine engines and generators were mounted on each unit. Black and Veatch proposed a field of heliostats, or individually tracking reflectors, central receiver, or collector, and Rankine cycle engine. Acurex proposed use of a field of single axis tracking, parabolic trough type solar collectors and Rankine cycle engine.

The Acurex design was selected for construction, appearing to have the fewest technical unknowns and be most economical at this time. The solar power plant consists of collector, energy storage and energy conversion subsystems, Figure 1. The collectors, six feet wide by ten feet long, have reflective parabolic surfaces of aluminum (Coilzak) and concentration ratios of 35 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. Total collector area will be about 49,000 square feet.

A heat transfer oil, Caloria HT43, is being used as the collector fluid. This oil remains stable and in fluid state at the temperature to which it will be heated, 550^{o}F. Therefore, low pressure flow can be utilized. For simplicity, energy storage is a 30,000 gallon tank of hot oil. On a sunny June day, enough energy can be collected and stored to provide about 20 hours of operation.

Energy conversion is accomplished by a Rankine cycle engine using a turbine and organic working fluid, toluene. The theoretical conversion efficiency, about 25 percent, is higher than for alternative types of thermal engines when peak cycle temperature is 550^{o}F. The engine, made by Sunstrand 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 conversion efficiency is expected to average 7 percent annually.

CONSTRUCTION AND OPERATION

The solar power plant is presently being constructed. Collector foundations have been poured, collector components are being delivered, and the engine is being tested. Collector and engine assembly at the site are expected to begin soon. Plant operational check-out tests are scheduled for summer and to terminate in September.

The solar installation then will be operated and operational data obtained and evaluated by the University of Arizona. The data will include environmental and operational parameters as well as a record of significant operational events and problems. Associated pumping, irrigation, and cropping experiments, begun in 1978, simultaneously will evaluate alternative energy use scheduling and conservation techniques.

ECONOMICS

Commercialization of solar power plants is dependent on the relative cost of energy. The energy costs depend on equipment performance and capital investment, fuel and operational costs. Solar power plants are presently being developed and evaluated. Thus, investment cost estimates are of doubtful quality and operational costs are almost nonexistent.

The experimental 150 KW solar power plant under construction in Arizona is costing over $10,000 per kilowatt of net peak output. Solar collector costs account for about half of this total. Improvements in collector and engine energy conversion efficiencies can reduce collector requirements. New design innovations, design for production and mass production can further reduce costs. Estimates of future costs for solar power plants manufactured in quantities of 1000 have ranged from less than $3,000 per KW. Cost competitiveness will depend on such factors as the cost of competing fuels, operational costs and interest rates (Larson, 1977; Katzman and Matlin, 1978).

Small, independent solar power plants might produce energy as inexpensively as larger plants. However, full utilization of produced energy is needed to minimize energy costs. Full utilization of a solar power plant, with variable solar input as well as variable demands, is difficult to achieve on a single farm (Larson, et al, 1978b). Interconnection with the utility company is a logical method to assure energy supply and full use of a solar power plant.

CONCLUSIONS

The Arizona 150 KW solar powered pumping experiment will provide an evaluation of a medium sized solar power plant using distributed collectors and much new technology. The application is most appropriate since irrigation demand peaks during the period of maximum solar insolation and a farm can provide a good environment for solar devices including adequate land area.

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 such 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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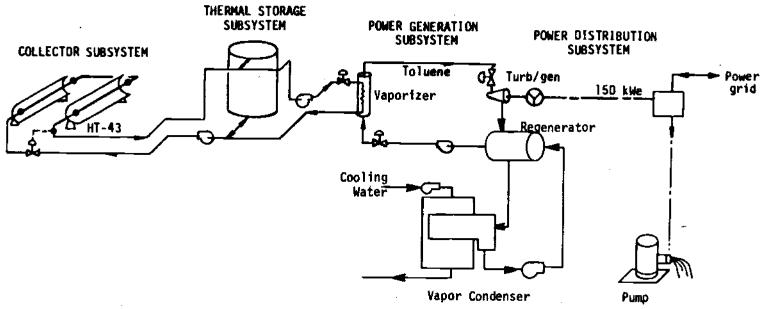

Figure 1. Schematic diagram of the 150 KWe solar-powered pumping facility (Acurex, 1978).