Conservation and Production Research Laboratory
Renewable Energy and Manure Management Research Unit
Bushland, Texas

Remote Water Pumping and Electrical Power Generation with Renewable Energy

Objectives.

1. Develop and evaluate autonomous wind-powered water pumping systems for irrigation, livestock, and farmstead water by developing controllers to increase the amount of useable energy available to the pump and by developing control strategies that prioritize and distribute electrical power to multiple loads.
2. Optimize the volume of water delivered for irrigation, livestock, and farmstead uses from various types of pumps using electricity produced from photovoltaic (PV) solar panels.
3. Measure engine performance and exhaust emissions of stationary engines used for electric power generation and irrigation pumping when fueled by biodiesel.

Accomplishments.

Wind Water Pumping

Designed a wind-electric water pumping system and found that the system operated maintenance free for over three years while supplying water from a 280 foot well for 75 beef cattle. The findings show that this new wind-electric water pumping system can be as reliable as utility powered systems. Several wind turbine manufacturers used the ARS control logic for their wind-powered water pumping systems.

Developed a wind-water pumping system to operate in low wind regimes by using a helical positive-displacement type pump. This system was able to meet the water demands by pumping water at a slower rate over longer periods of time. Two international pump companies are marketing this type of system using wind turbines manufactured by a United States wind company.

Determined that wind power usage for irrigation did not match the periods of significant crop water use unless the producer was growing mostly winter wheat. Also a producer needed to be in a location that allowed for net energy billing of the electricity to receive a profitable return for the excess energy generated during the non-irrigation periods. This analysis led to searching for other rural energy users that better matched the available wind resources. Recent analyses have suggested that dairies, feedyards, and rural schools are better matches to the wind resource than irrigation. Methods of performing these analyses have been provided to electric cooperatives and wind turbine manufacturers. Several rural schools have purchased wind machines in the last year.

Solar-Water Pumping

Demonstrated that 100-Watt DC solar-powered, one gallon per minute diaphragm-type water pumping systems operated for six years when pumping water from a depth of 100 feet. The system pumped water sufficient for 25 head of cattle. When comparing fixed panel solar systems with those having passive solar tracking, it was also found that the additional water flow obtained by use of passive solar tracking did not warrant purchase of the tracking equipment. This research shows that solar-powered diaphragm-type water pumping systems are reliable for supplying livestock needs as long as the pumping depth does not exceed 100 feet.

Conducted solar photovoltaic (PV) water pumping field studies to evaluate the use of helical pumps for watering livestock. A helical pump powered by either 480 or 640 Watts of PV modules was evaluated to determine the optimum power requirements for pumping depths from 50 meters (164 feet) to 100 meters (328 feet). This pumping system did not show a significant change in performance during three years of operation. Because of the capability to pump water over a wide range of pumping depths, these solar powered helical pump systems now appear to be the preferred stand-alone water pumping system for large herds (75 to 160 cattle).

Wind Turbine Design

Wind turbine rotor and tower designs have been oversized because of the inability to capture peak wind loads caused by peak winds. Long-term continuous data sets were not feasible because of limited data acquisition systems. Working with Sandia National Laboratories, data acquisition hardware and software were developed to acquire continuous, long-term data from an operational wind turbine. This data acquisition allowed for the simultaneous collection of stress loads from the rotating rotor, incoming wind speed, and power output. Sampling rates were at 30 times per second with over 60 data channels recorded. Continuous data sets of over 1000 hours provide the type of long-term data needed to improve wind turbine designs. The capabilities of this system and methodology are currently used to atmospheric test the new advanced wind turbine blades developed from carbon fiber for performance and turbine structural loads. Commercial applications of this data acquisition system are currently being used in many research applications and control systems.

In cooperation with Sandia National Laboratories, Albuquerque, New Mexico, a set of instrumented blades that were designed with improved materials were tested on the 115 kW turbines located at the USDA-ARS research laboratory at Bushland, Texas. These blades were constructed using a new fabric incorporating carbon fiber and fiber glass. This resulted in a lighter and stronger blade while still maintaining the power production of the original blade design. Power production slightly exceeded the output of original blades and structural loads were less than design models predicted; indicating the blades are superior to current production blades. This improvement will allow for future utility scale blades to be transported easier as well as less wear and tear on the turbine components. The improvements could potentially allow turbines to be built in more remote areas on farms and ranches, for distributed energy production, as well as large wind farms.

Wind/Diesel Hybrid Electric Power Generation

ARS engineers designed and installed wind-hybrid diesel controls for remote electric power generation in cooperation with the Department of Energy's National Renewable Energy Laboratory (DOE/NREL) and contractors Encorp and Northern Power Systems. These controls were designed to allow for high penetration of wind power on a diesel electric grid whereby the diesel generators could be completely shut down during periods of high winds for maximum fuel savings. An average fuel savings of 22% was measured during almost 1000 hours of operation and all control transitions were smooth and stable. The system was successfully operated in a wind-only generation mode providing stable electric power. The fuel efficiency increased from 2.63 kWh per liter for diesel only to 4.01 kWh per liter with hybrid system without storage and to 10.09 kWh per liter with battery storage. The potential run time in wind only was increased from 2% without storage to 26% when the battery storage was added.

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