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WIND-ASSISTED IRRIGATION PUMPING[1/]

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ABSTRACT

A wind-assisted pumping system has been designed for use with an existing irrigation well and vertical turbine pump. The system has operated satisfactorily and has effectively utilized the unsteady power output of a wind turbine. Wind-assisted power systems can be utilized in any rural or remote application where a second power source is available.

INTRODUCTION

Windmills have been used for centuries to pump domestic and livestock water, but the pumping capacity and lift are not adequate for practical irrigation. At their design windspeed, modern wind turbines can provide all of the power required for most irrigation wells. The unsteady power output at lower windspeeds, however, is not suited to powering vertical turbine pumps.

In an effort to utilize wind power with existing wells and pumps, a wind-assisted pumping system was tested at the USDA Southwestern Great Plains Research Center, Bushland, Texas. This paper describes the major system components and summarizes operating data for the system.

PUMPING SYSTEM

The pumping system utilizes both a wind turbine and an electric motor to power a vertical turbine pump (Fig. 1). The electric motor is sized to operate the pump on a stand-alone basis and runs continuously. The wind turbine is coupled to the pumpshaft through an overrunning clutch and combination gear drive and furnishes power only when the windspeed exceeds 6 m/s (13 mph). The wind turbine, thus, reduces the load on the electric motor rather than replacing the motor.

1/ Contribution from Agricultural Research, Science and Education Administration, USDA, in cooperation with The Texas Agricultural Experiment Station, Texas A&M University, and the Alternative Energy Institute, West Texas State University.

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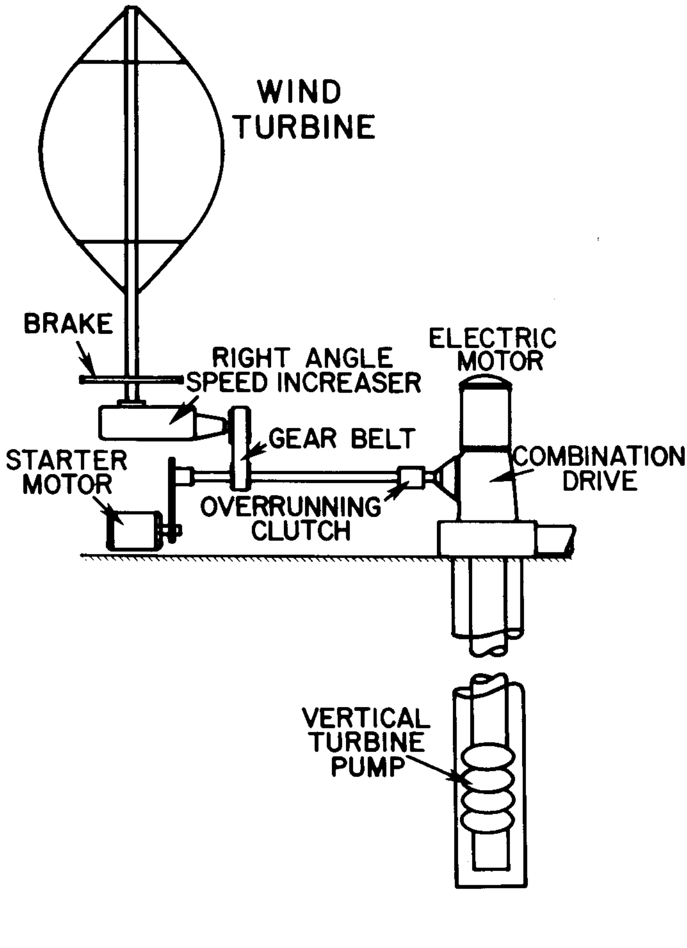

Fig. 1. Schematic of the wind-assisted irrigation pumping system.

Wind Turbine

The Darrieus, vertical-axis wind turbine was designed to produce 40 kW (54 hp) in a 15-m/s (33-mph) wind (Fig. 2). The rotor is 16.7 m (55 ft) high and has an equatorial diameter of 11.3 m (37 ft). It sets on a 9.1-m (30-ft) stand-alone steel tower and is supported at the top by four 22.2-mm (7/8-in.) galvanized steel cables. The chord length of the symmetrical airfoils forming the blades is 356 mm (14 in.). A 3.7-kW (5 hp) starter motor is required because Darrieus wind turbines are not self-starting.

Mechanical Drive

The wind turbine was designed to operate at 90 rpm, but the pump operates at 1,780 rpm. For this reason, a high-ratio speed increaser is required in the drive train. The vertical drive shaft of the wind turbine connects directly to a two-step, right angle speed increaser with a 1:15.4 gear ratio. A timing belt further increases the overall speed ratio to 1:19.8. With this ratio, the 90-rpm rotor speed is converted to a 1,782-rpm horizontal shaft speed.

Since wind power is intermittent, a clutch is required which engages only when the wind turbine is producing power. The horizontal drive shaft connects to the combination gear drive through an overrunning clutch. The overrunning clutch allows the electric motor, combination gear drive, and pump to operate independently of the wind turbine. The wind turbine can be stopped or can coast below operating speed without affecting the pump. When the turbine reaches its operating speed of 90 rpm, the overrunning clutch engages to transmit wind power into the combination gear drive.

A 750-mm (30-in.) disk brake with three calipers is used for normal or emergency shutdown of the rotor.

Pump and Motor

A 200-mm (8-in.) vertical turbine pump, installed in the well in 1964, was used without modification in the pumping system. The well produces approximately 91 m^3/hr (400 gal/min), and the total dynamic head on the pump is about 100 m (328 ft).

The induction motor used to power the pump is a three-phase vertical, hollow-shaft type normally used with vertical turbine pumps. The 56-kW (75-hp) motor has a full load operating speed of 1,780 rpm, the same as the pump. In addition to being the primary power source, the electric motor controls the speed of the wind turbine. When the overrunning clutch engages, the wind turbine partially unloads the electric motor. Since the wind turbine provides less power than the motor, the motor speed varies between 1,780 rpm and 1,800 rpm, the synchronous speed of the motor. This maintains the rotor speed at 90 rpm or slightly more.

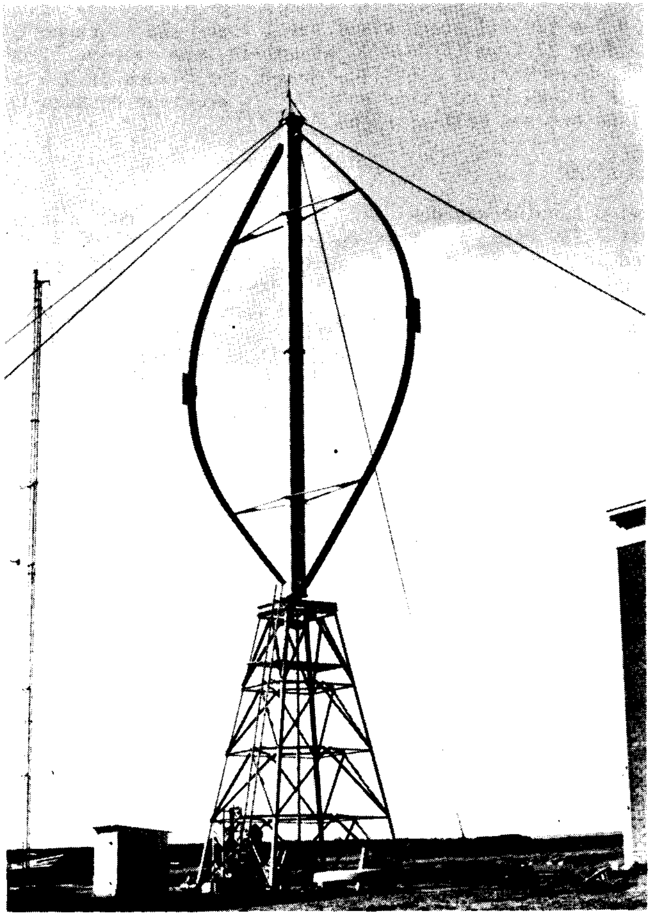

Fig. 2. Forty-kilowatt Darrieus wind turbine with a 17-m high by 11.3-m wide rotor mounted on a 9.1-m tower.

RESULTS

System operating performance with a rotor speed of 90 rpm is summarized in Fig. 3. The curves are a regression of all data collected in several tests between 30 June and 18 Sept., 1978. Detailed results of a test on 18 Sept., 1978, were discussed by Clark and Schneider (1978).

The curves show the operating characteristics of the wind-assisted pumping system with windspeed ranging from 6 to 20 m/s (13 to 44 mph). The rotor output was measured with a torque transducer at the base of the rotor centershaft. Turbine system power was measured with a torque transducer in the high speed horizontal shaft. The difference between the two is the power lost in the speed increasers, about 9%. The sum of turbine system power and electric power is the pumping system power. This curve shows the constant power of about 51 kW (68 hp) required by the vertical turbine pump.

DISCUSSION

The wind-assisted pumping system effectively utilized the unsteady power output of the wind turbine. The system has operated satisfactorily, and the concept has proven to be sound. All components are readily available and proven and the mechanical drive is simple. The overrunning clutch has proven to be a simple and reliable method of synchronizing the two power sources. Any correctly sized wind turbine could be mechanically connected to the system and operated at constant speed.

If wind turbine power exceeds the total load on the system, the induction motor will be driven above synchronous speed and become an induction generator. Pump output will increase according to the pump speed laws, and electricity at the correct voltage and frequency will flow back into the power grid. With this design, the wind turbine can be sized twice as large as the electric motor.

A diesel engine could be substituted for the electric motor in the wind-assisted pumping system. Diesel engines operating at constant speed can be throttled from 100% to 25% load with a corresponding reduction in fuel consumption. The wind turbine should not be sized to provide more power than that required by the pumping system. Wear on the engine would then be very rapid because the engine would brake the wina turbine at high windspeeds. A spark ignition engine such as a natural gas engine is not as well adapted to the wind-assisted system as a diesel engine. These engines require a minimum fuel:air ratio for ignition, and little or no fuel saving occurs below 50% of rated power.

The wind-assisted concept can be used in any rural or remote area where a second power source is available. Practical use will depend on whether wind energy is more economical than existing energy sources.

REFERENCES

Clark, R. N., and A. D. Schneider. Irrigation with wind energy. ASAE Paper No. 78-2549, Am. Soc. Agric. Eng., St. Joseph, MI.

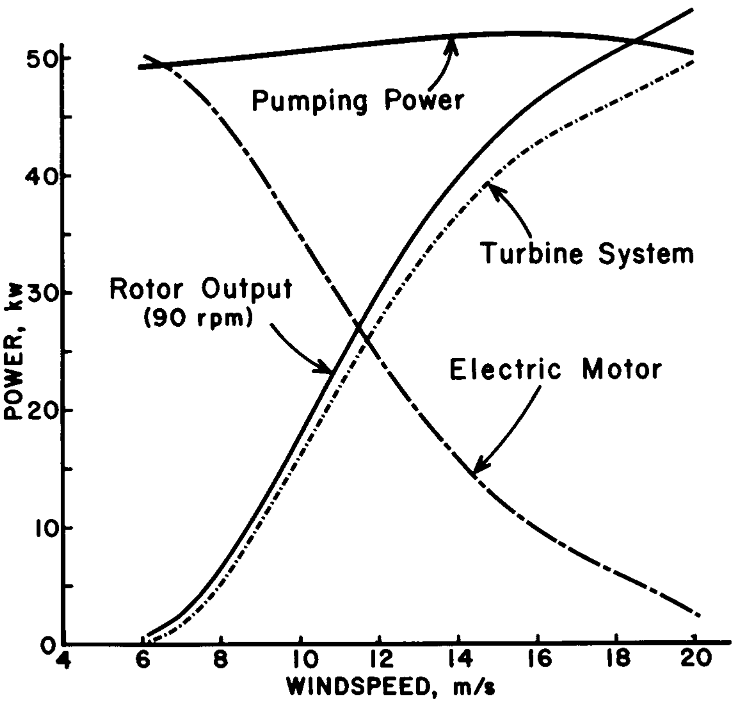

Fig. 3. Rotor output, turbine system power, electric motor power, and pumping system power versus windspeed.