Wind Harvest Company Prototype - Windstar 530

Whitewater, CA | Installed 1988, Removed 1994

The model 530 was designed for Chinese manufacturing, first starting with a prototype.

Model 530 Specifications	
Rotor Height (m)	25
Rotor Diameter (m)	5.4
Swept Area (m^2)	161.5
Blade length (m)	3
Blade cord (m)	.44
Stator cord (m)	1.1
Number of modules	3
Number of blades per module	4
Number of stators	5
Rotor RPM	80
Solidity	33%
Generator	Induction
Voltage	460
# of phases	3
Generator RPM	1810

The turbine was constructed in the following manner:

1. The frame was constructed of square and rectangular steel tubing stabilized with steel rods.
2. Each module was assembled separately on the ground and lifted into place and bolted to the previously installed module.
3. The turbine was erected by stacking the modules on top of each other starting with a base frame. This allowed for assembling the modules at ground level.
4. Blade support arms were made of steel channel similar to American standard channel.
5. A fairing of rolled and riveted galvanized sheet metal covered them.
6. The arms were attached to a shaft flange with blade weight supporting struts attached to the arms 3ft out from the shaft.
7. The other ends of the struts were attached to the shaft.
8. The struts provided support in both tension and compression.
9. The attachment point on the blade arm was a plate welded to the arm.
10. The blade was connected to the arm at a plate welded on the end of the arm.
11. The bottom blades were attached so that they were able to pitch in the turbine-braking mode.
12. The blades were fabricated aircraft style; semi-monocoque construction. T
13. he profile was the NACA 0018 shape.
14. Flanges were attached (with rivets) to the blade ends to provide a connecting surface to the blade arm plate. They were fabricated at a Chinese aircraft factory.
15. Each module had its own brake and the three brakes were simultaneously activated, (similar to the model 480-5 turbine).
16. Brake force was provided by three weighted fulcrums. A winch was used to lift the weight and brake arm (the fulcrums) assembly to disengage the brake. (Note- we tested this design on the 480-5 turbine.) The winch ratchet stop was released to engage the brakes. The release mechanism was activated when rotor speed exceeded a preset value. Brake shoes mounted on the short end of the fulcrum pressed against a disc that was allowed to rotate through a fixed angle. The blades were shaft mounted so they could pitch but only when the brake was engaged. Consequently, the rotor was stopped by both aerodynamic drag and mechanical friction forces. Each rotor had a brake to avoid a potential catastrophic inter-module shaft failure. Also, a trip cable was stretched vertically just outside the blade path so if a blade should fail, the cable would trip the brake winch. The brake system was quite effective in stopping the turbine in high winds, however, the blade pitch did not work as planned because the blades pitched during generation. After trial

and error, the problem was solved, and we observed a significant increase in monthly energy output.

17. A US manufactured shaft mounted gearbox and belt drive parts were used. A Chinese 25kw induction generator was initially employed but soon failed. We used a US generator (25kw) after that.
18. The controls were made up of a tachometer sensor and switch, (a Danish design) which activated an Enerpro generator soft start. It employs solid state switches, one for each phase. This system worked well. Two sheave sets were used independently so the turbine rotor operated at two different speeds depending on the sheave set used. The rotor operated at either 79 or 89 RPM. We tested at both speeds.

Testing

A utility watt hour meter continuously measured energy output. It was recorded periodically. Power and wind speed were measured using the NRG Power Curve Monitor, their lowest cost monitoring system at that time. A power transducer came with the system. Power and wind speed measurements were binned and stored for manual retrieval. The anemometer cup was mounted at mid-rotor height, three rotor diameters up wind of the turbine. Energy winds are directed by topography there, and are unit-directional out of the west. The turbine began to produce net positive power at a blade speed ratio of about 3.6.

Maximum monthly energy registered on the watt hour meter was over 7000 kWh. This is a somewhat lower amount than what should have been produced because the turbine shut down in gusts around 45mph. Several observations were made to determine what was causing these interruptions, and it was discovered that the generator belts started slipping (generally at night), which activated the over speed trip mechanism. It never tripped while we were there so it took awhile to solve the mystery. At that seasonal period, winds started building in early afternoon reaching peak intensity in the middle of the night, then they slowly slacked off to a low around noon the following day. We encountered weld fatigue problems, and some frame rod connecting bolts sheared. Fatigue problems occurred with the blade support arms at the welds. We lost several blades because the support struts of the blade arms failed causing the blade arms to strike the frame thus destroying the blade and its support arm. But with replacement parts we continued to operate. Close inspection of the failed parts at the welds revealed that the welds had crystallized, and a crack formed with corrosion forming in the crack. The stress cycles progressively caused failure. The lesson learned was, ‘no welds in the rotor design unless properly heat-treated and inspected.

This proved to be a valuable lesson. In subsequent designs, welds were not used in rotor parts and there has been no rotor component fatigue failure since. Bolt shearing problems were dealt with by using US bolts and by making sure that the shear plane did not pass through the thread section of the bolt.

We were encouraged to press on with the technology because of the good monthly output, (even with overnight shutdowns), good blade aerodynamic and structural performance and only two minor design problems that were solved. We felt that durability issues were addressed, we now had to improve the output to cost ratio. Hence, we designed a single module 50 kW turbine.