Battery Charging with a Small Downwind Horizontal-Axis Wind Turbine

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INTRODUCTION

The Synergy 5000DD wind turbine has been operated for battery charging at Bushland, Texas for 1.5 years. The Synergy 5000DD wind turbine has a uniquely designed furling system. The downwind horizontal-axis wind turbine furls by the tail lifting the rotor and alternator from a blade rotor horizontal-axis position to a blade rotor vertical-axis position (e.g. similar to a helicopter) at moderately high wind speeds. This 3.5 meter diameter wind turbine was installed on a 19.5 meter tilt-down guyed tower at the USDA-ARS Conservation and Production Research Laboratory in Bushland, TX in the summer of 2001. The battery charging capability of this wind turbine is currently being investigated. Parameters which are being measured include: wind speed, wind direction, air temperature, barometric pressure, wind turbine AC voltage, wind turbine AC power, wind turbine frequency, battery voltage, charging current to the batteries from the controller, and load current from the batteries to the resistive loads (e.g. electrical lights).

Synergy 5000DD in low to moderate winds (WS < 13 m/s)

Synergy 5000DD Furling in high winds (WS=18 m/s)

48 Volt Battery Charging Controller

The main function of the controller is to convert the 3-phase AC variable voltage/frequency electricity from the wind turbine into DC electricity for charging the batteries. A brake switch connecting the wind turbine to a dump load can brake the wind turbine at low wind speeds. If the batteries risk being over charged (e.g. the battery voltage exceeds 56 Volts), the controller goes into choke mode where most of the electricity from the wind turbine is diverted to inductors in the controller. When the battery voltage drops below 55 Volts, the wind turbine electricity is diverted back to the batteries and the electrical load. See the graphs below under the label "**Prevention of Over Charging**" for an example of this. For a normal charging sequence (battery voltage stays between 44 and 56 volts) look at the graphs under the label "**Normal Charging**". We had to install a quick disconnect switch between the controller and batteries to keep the controller from discharging the batteries completely during wind turbine downtimes over 14 days. We also installed a relay and timer switch between the batteries and load bank to keep the batteries from being discharged excessively.

Load Bank

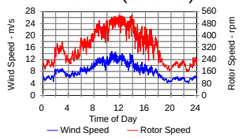
Resistive electrical loads of 4, 8, 12, and 16 Amps were tested on this wind turbine. The four lights on (see picture to right) are 12 Volt/ 50 Watt lightbulbs. Switches below the lights turned on a separate string of four lights.

Batteries

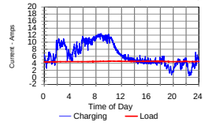
These are the four 12 Volt deep cycle 100 Amp-hour batteries connected in series (48 Volts) used in the battery charging testing.

Prevention of Over Charging

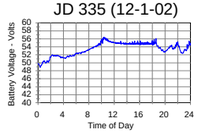
Wind and Rotor Speed
JD 335 (12-1-02)



Charging and Load Current
JD 335 (12-1-02)

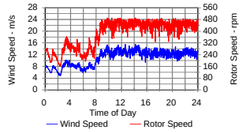


Battery Voltage
JD 335 (12-1-02)

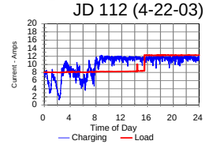


Normal Charging

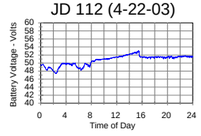
Wind and Rotor Speed
JD 112 (4-22-03)



Charging and Load Current
JD 112 (4-22-03)



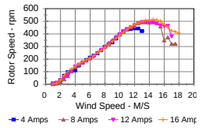
Battery Voltage
JD 112 (4-22-03)



Effect of Varying the Electrical Loading

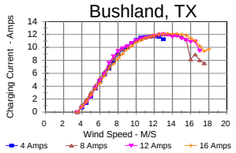
The wind turbine was seen to begin furling (turn out of the wind) at a wind speed of about 13.5 m/s. This was verified by the rpm peaking at a 13.5 m/s wind speed. The wind turbine was seen to be fully furled (helicopter position) at wind speeds above 20 m/s.

Synergy Rotor Speed
Bushland, TX

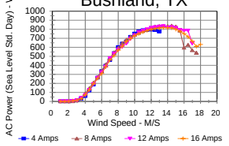


The charging current to the batteries never exceeded 12.5 Amps due to the current limiting rectifier in the controller.

Synergy Charging Current
Bushland, TX



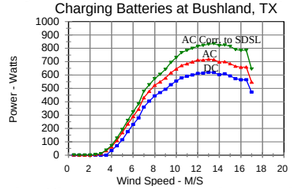
Synergy AC Power
Bushland, TX



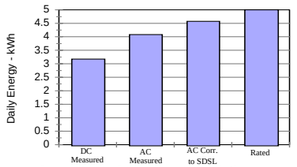
The AC power corrected to standard day sea level (SDSL) conditions was independent of the electrical load except at high wind speeds.

Power and Energy Produced

Synergy Power (12 A Load)
Charging Batteries at Bushland, TX



Synergy Energy (12 A Load)
Rayleigh Wind Dist.(WS=4.5m/s)



The DC power output from the controller was about 15% less than the AC power generated by the wind turbine. Another power curve is shown where the AC power from the wind turbine was corrected to sea level standard day conditions. Assuming a Rayleigh wind distribution with an average wind speed of 4.5 m/s, the usable energy produced with this wind turbine was 3.2 kilowatt-hours. This is less than the rated energy of 5 kilowatt-hours.

CONCLUSIONS

The wind turbine was shown to reliably charge batteries with the windy conditions and extreme temperature variation at Bushland, TX. When the wind turbine was down and not charging the batteries, we found it necessary to install a disconnect switch between the batteries and the controller, so the controller would not discharge the batteries. In order to achieve the rated energy production, the current limitation on the controller rectifier will need to be increased.