Aurora Christine's Performance in the 2007 World Solar Challenge

Greg Locock November 2007

Christine was originally built by the Ford Solar Car team for the first World Solar Challenge, in 1987, coming second. In 1990 she raced again, as the AERL entry, coming 6th. After a race in Japan in 1992 we retired Christine to the Ford Discovery Museum, in Geelong.

In 2007 for the 20th anniversary of the first event we dragged her out of retirement, installed a new array, motor, brakes, array tilt mechanism, instruments, batteries, wheels, tires, motor controller, maximisers and pedal box. We waited for a lightning storm and then Igor threw the switch.

The rest is history.

The picture on the right shows the charge session in Alice Springs. The batteries are balanced on the back of the cockpit, so that we could measure the voltage of each of the 39 cells, as the battery approached 100% capacity at 11 in the morning. The upper suspension member operates the shock absorber (inside the body), the middle one is the tie rod, and the bottom one is also the leaf spring that supports the weight of the car.

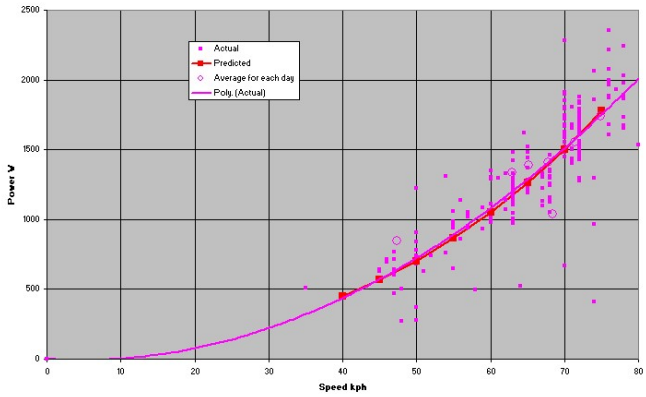
	Units	1987	1990	2007
No of wheels		4	3	3
Brakes		Disc brakes all round	Cable drum brakes all round	Hydraulic drum brakes on front wheels Hydraulic disc brake on rear
Transmission		chain drive, 5 speed gearbox, differential	fixed ratio chain drive	Wheel motor
Motor		Industrial Drives brushed DC	Industrial Drives brushed DC	Aurora/CSIRO wheel motor
Motor efficiency	%		89	98
Motor Controller		AERL?	AERL	Tritium Gold
Maximisers		AERL	AERL	AERL
Photovoltaic cell efficiency	%	16.5	mixture of 16.5 and 10	20
Panel tilt mechanism		Manual	Manual	Electric
Array peak Power	W	1180	950	1500
Tires		Michelin bicycle	Michelin/Avocet bicycle	Dunlop/Michelin radials
Battery type		Yardney Silver Zinc	Gates Lead Acids	Kokam Lithium Poly
Battery capacity	kWh	3.4	1.5	5.7
Battery mass	kg	39	50	40?
Vehicle mass without driver	kg	189	169	190
Average race speed	kph	44.5	50	64
Race Position		2	6	12?

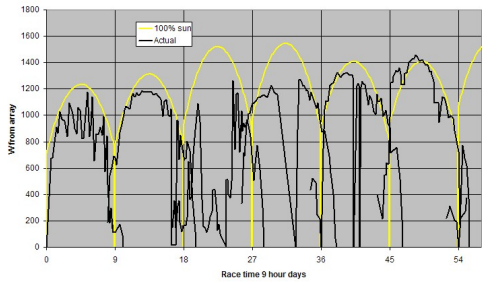
This graph shows the measured power and speed data. This includes gradients and wind, so it is slightly pessimistic on average. The trend line is a parabola as this gave a better fit than a cubic.The red line is the best fit I could get using the following model

Power(W)=v/eta*(Mass*Crr*g+$^1/_2$*rho*Cd*A*v^2)

where v is the speed in m/s.

Mass	kg	270
Cd		0.33
A	m^2	0.7
rho	kg m^{-3}	1.22
g	m s^{-2}	9.81
Crr		0.0085
overall eta		0.98





Here's a comparison between the array power we'd expect, based on the measured insolation seen in the first three events, with 20% cells, and what we actually got.

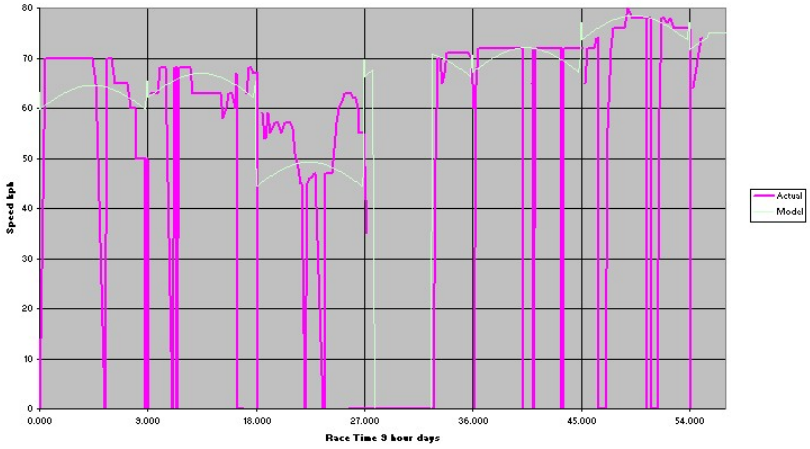
The array power goes to zero when the battery is fully charged, or when the array is switched off.

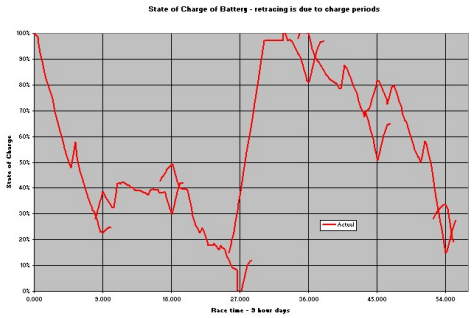
The morning and evening charge sessions are included, which is why the lines overlap. These peaks are much fatter than you get with a wing type array, as we could run with the panel tilted from 8 in the morning until about 1030 am, and similarly in the afternoon. This worth about 16% more energy over a typical day.

This data is logged on a Fluke averaging multimeter, read every 10 minutes or so.

Here's the speed plot also showing what the strategy would have been if we'd known the weather in advance. Not bad. The curve each day is to minimise the peak current drawn from the battery.

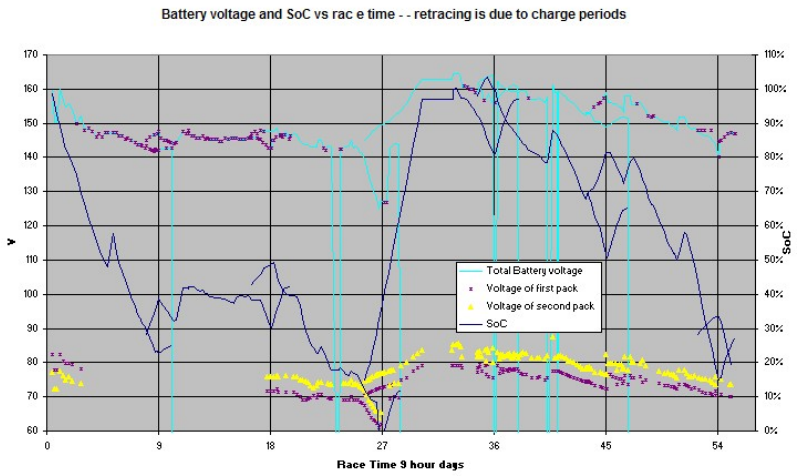
We changed speed a bit at the start of each session, trying to figure out what the wind was really doing. Also the speed on the first day was a bit of a guess, as we hadn't got any good data for the speed vs power curve.





This shows the measured state of charge of the battery. Current into and out of the battery was logged using a Fluke averaging multimeter, read every 10 minutes or so. Again, the charge sessions are included which is why it jumps around. We hit the battery hard on the first day, hardly used it on the second, and flattened it completely on the third day. We charged it fully in Alice, and again on the 4th evening.

This has the battery voltage superimposed. We split the battery into two halves and could measure the voltage of each half. There were 20 cells in one and 19 in the other, so we'd expect around 3.7-4 V difference between them. Sometimes we just measured the total bus voltage instead. This voltage difference is very important when approaching the limits of the battery.



Here's the summary of each day's racing. On Wednesday we were held at Alice until 1340, which is why the overnight charge session is so big. 1360W is enough to drive the car at 66 kph, so an average speed of 64 kph is not bad at all.

		Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Total
km start	km	0	536	1063	1494	1725	2333	2925	
km end	km	536.3	1063.3	1493.5	1725	2332.6	2925.3	2998.3	
Time start	hhmm	817	800	805	1340	805	806	801	
Time end	hhmm	1718	1705	1710	1705	1706	1701	905	
media stops	h	0.5	1			0.5	1		
race hours	h	8.5	8.1	9.1	3.4	8.5	7.9	1.1	46.6
solar on move	kWh	7.04	10.74	4.88	3.80	10.50	10.65	0.29	47.90
solar o/n	kWh	0.94	1.13	1.13	5.63	1.03	1.08		10.94
Batt start	kWh	5.63	2.21	2.81	5.63	5.63	3.97	1.91	
Batt end	kWh	1.29	1.70	0.00	4.61	2.89	0.86	1.09	
daily distance	km	536.3	527.0	430.2	231.5	607.6	592.7	73.0	2998.3
AVE SPEED	kph	63.0	65.2	47.4	67.8	71.3	74.9	68.4	64.3
	Wh/km	21.2	21.3	17.9	20.8	21.8	23.2	15.2	21.5
ave power	W	1336.3	1390.6	846.9	1409.8	1554.2	1738.1	1037.9	1360

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