Going Solar
on
Wheel-chair
A low cost development

by
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The initial thought - Basic design considerations

While photovoltaic electricity has become the standard for remote situations such as water pumping, telecommunications, rural homes, few have thought of its application and developed cost-effective end products for areas with grid power. The target was to construct an *inexpensive solar-powered electric wheel-chair* for the needy people, fully autonomous in and outside the house, easy to move around, and easy for anyone to fold it and carry it in a car trunk, if necessary.

Market research and final decisions

Knowing that the most expensive component would be the solar panel, and in order to cut down cost, a pre-study stage was undertaken followed by a thorough market research. Estimated sizes of electric motors, batteries, PV panels, controllers and wheelchairs were looked upon. At the end of a three month period of *search-find-and-reestimate,* this is what it was decided to follow through:

a) To purchase an inexpensive brand new *hand-driven* (simple, nonelectric) wheelchair built on standards and then modify it according to plans.

b) To use two electric motors, one per wheel, that could run each wheel independently forward and backwards, easy to find in the auto-parts at a very low price.

c) To purchase a made-to-order speed controller able to run each motor smoothly at will, and another one to regulate battery charging from the PV panel, or from mains using a quick battery charger.

d) To use permanently sealed 12 V lead-acid batteries, placed firmly under the seat, and mounted on wheels that could be easily drawn out with a sliding action and roll away, i.e. when folding the chair, or when having an off-the-chair-battery-recharging supplied by either the PV panel, or the 220 V ac electric fast charger.

e) To size the PV panel array such as to provide 100% energy autonomy in running the wheelchair for at least 2.0 hours per day, throughout the year (using solar radiation data from measurements taken in Athens, Greece), under heavy duty conditions.

Components and sizes

The purchased wheel chair constitutes of a heavy-structure folding-type standard ISO size wheel chair. It had to be reinforced with steel beams for the battery racks, and metal pipe side stands with butterfly screw locks to hold the overhang PV panel.

Mounted on the main frame structure, at each side under the seat, and supplying power to the corresponding wheel axis is the power unit. Each power unit (elecric motor and speed reducer together) is a common 24 V dc windshield-wiper motor rated at 120 W max power and having a nominal speed of 32 RPM at zero load. It is the type used in heavy trucks and it sells rather cheap. Power trasmission to the wheel axis is made directly from the reducer side by a specially made joint.

The two sealed 12 V lead acid batteries, rated at 55 Ah each and connected in series, provide enough power to move both the chair and the rider around for up to 5 hours per day, with still enough energy left to prolong battery life.

Based on initial calculations, an average array efficiency of 9% showed the need of a PV supply of 100 W_p . It is provided by the two KYOCERA LA361 K51S PV array panels connected in parallel and rated (each) 51 W_p , 16.9 V and 3.02 A at max. power, 21.2 V open circuit voltage, and 3.25 A shortcircuit current.

Results and performance tests

Several sensitivity and performance tests were run on the chair-and-driver system, in real situation, under various solar irradiance levels and driving conditions, in order to obtain wheel chair mobilability and performance of the power mechanism as a whole.

All tests were run on site at the T.E.I campus, during May 1995. The following instruments were used in measurements and data processing:

1. CR 21 Micrologger, Campbell Scientific Inc.
2. CM 11 Kipp & Zonen precision pyranometer
3. Tag & Heuer digital chronograph
4. DM-205 Hung Chang digital multimeter

With the wheel chair weighing empty a total of 72 kp (57 kp without the PV panels) a rider weighing 85 kg and zero ground inclination, the maximum speed attained was 0.85 m/s. Nevertheless, with proper tire pressure (solid tires promise a better performance) and same load, this figure could probably rise to 1 m/sec. Varying the load and angle of ascend, climbing ability measurements of the chair taken on paved surface gave results shown in Figure 1. In addition, with a rider weighing 85 kp, the chair overrun obstacles up to 6 cm tall showing no signs of instability, or motor fatigue.

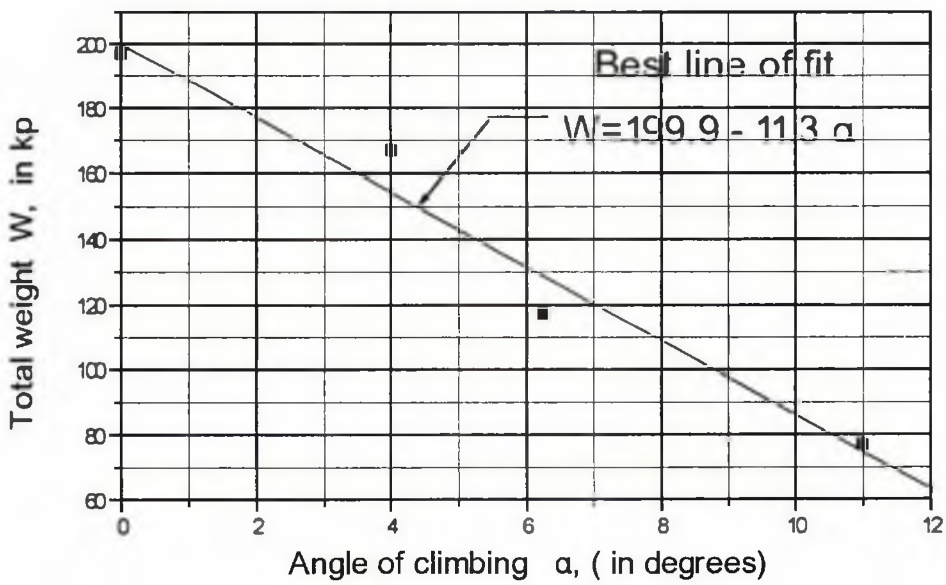

Figure 1. Wheel chair's climbing ability, measurements and best line of fit

Some tests were run inside without the PV panels, on flat and paved horizontal surface, with a rider weghing 93 kp. This is what it came out:

Forward motion : 0.86 m/s max speed attained in 7 sec after a 3 m run
Backward motion : 0.80 m/s max speed attained in 5 sec after a 2 m run
One wheel blocked : A full turn in 6 sec
Two wheels in adverse rotation : A full turn in 4.3 sec
Smooth full stop from max speed (0.86 m/s): It took 2.5 sec and 1 m distance
Abrupt stop from max speed (0.86 m/s): It took 1 sec and 0.5 m distance

Several 100 min field-tests were run, some of them under harsh and scorching conditions (heavy loads, driving uphill at full speed motion and temperatures near 35°C), with solar irradiance measuring up to 1030 W/m². Starting with a fully charged battery and the PV panels in horizontal position, measurements regarding voltage-current supply and demand were taken at 5 minute intervals. Under these hard driving conditions, evaluation of the average energy requirement of the wheel chair gave **0.27 MJ per hour**. Considering a 28% battery discharge level, this energy load could be continuously supplied by the batteries for 5 hours.

Table 1. shows the current drawn at the tests, by *each motor,* under all possible operation schemes and driving conditions.

Table 1. Motor current requirements

Operation scheme	Current drawn (A)
Starting to move forward on flat paved surface	5.37
Normal forward operation on flat paved surface	1.13
Abrupt turn on flat paved surface	3.5-4.0
Open turn on flat paved surface	2.23
Starting to move backward on flat paved surface	4.22
Normal backward operation on flat paved surface	0.48
Going uphill (maximum speed)	6.22

Solar energy availability and PV panel' s output

In order to estimate the PV panel's energy contribution and system performance regarding voltage-current supply and demand, four types of days were considered representing a variety of solar radiation levels, specifically, (a) the average December day, (b) the maximum December day, (c) the average March day, and (d) the average June day. For each type of day, hourly solar radiation values were calculated from solar irradiance data (3 years) logged at the T.E.I. measuring station. Figure 2. shows the hourly global solar radiation distribution for each day considered.

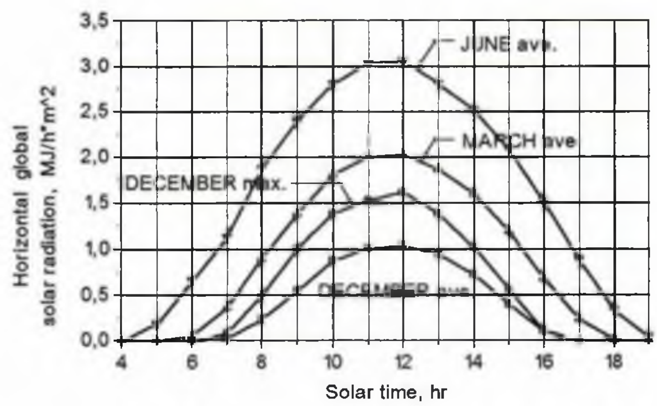

Figure 2. Global solar radiation hourly distribution on the horizontal plane for the average December day, maximum December day, average March day, and average June day in Athens, from measurements at the T.E.I. station

The PV panel's power efficiency and energy output were then calculated. Results show a rather steady form in power efficiency ranging from 8.6% at (or close to) 1000 W/m^2 to 9.6% at 700 W/m^2 to 8.8% at 170 W/m^2. Energy output results representing the useful energy supplied to the batteries from both PV panels, for each hour and day-type considered, are then shown in Figure 3.

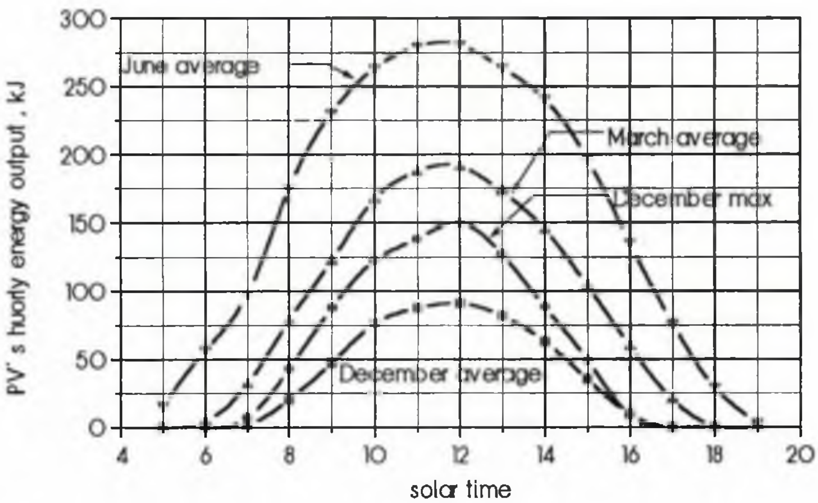

Figure 3. PV panels hourly energy output, in kJ, supplied to the batteries, for the duration of the average December day, the max December day, the average March day and the average June day

Finally, for each day-type considered, a full day's charge from the PV panels to the batteries, is enough to run the wheel chair on the next day, *under heavy driving conditions*, for a total of,

1.9 hours average in **December**
3.0 hours maximum in **December**
4.8 hours average in **March**
8.7 hours average in **June**

Figures 4, 5, 6 and 7 show the wheel chair at different situations.

Figure 4. Strolling on the outside. A real enjoy of PV panels provided power and sun protection.

Figure 5. A rear view of the wheel chair with the PV panels retracted.

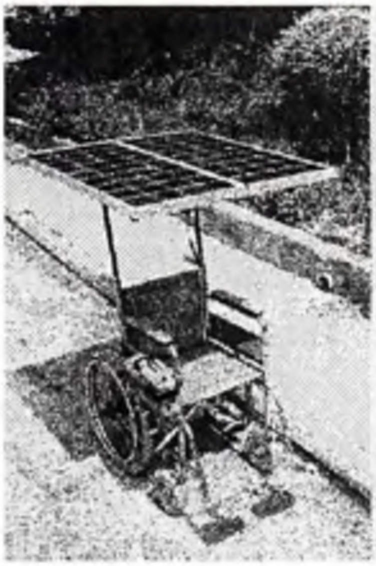

Figure 6. A front view with the PV panels on their mountings and the speed-direction switch controller on the right arm rest

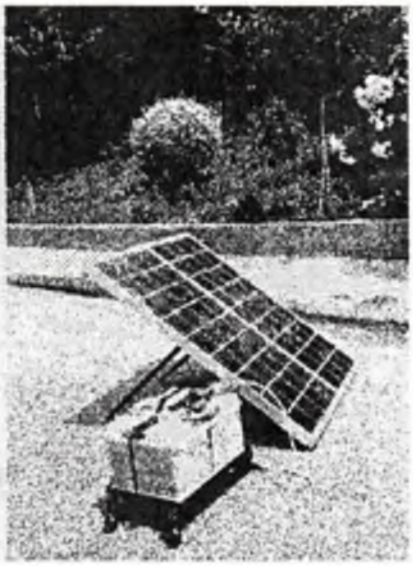

Figure 7. Battery charging with the PV panels removed from the chair.

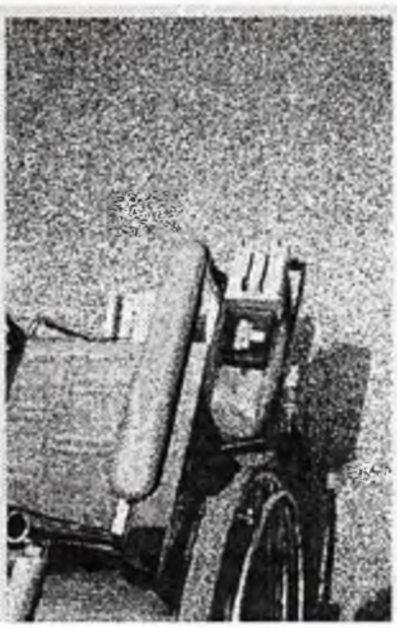

Figure 8. Details of the speed and direction controller shown next to the battery charge level indicator.

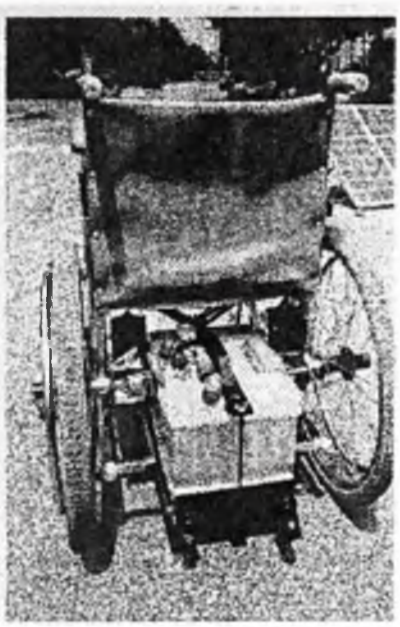

Figure 9. A rear view of the chair's under carriage showing battery rack in position, and the two dc motors mounted on each side.