The Solar-Powered WASTE RECLAMATOR

Chris Laughton

Above: The Reclamator with one of its three PV arrays in place.

While staying with friends in Scotland during the Christmas break of 1996, I met the owner of a rather unusual piece of equipment The Waste Reclamator. This machine is a flat-bed trailer holding a four meter (thirteen foot) long conveyor belt to sort out waste at fairs and festivals around the UK. Collected trash from an event is tipped into a galvanized steel chute at one end of the moving belt, allowing a line of people to pick reclaimable items. Remaining debris tumbles off the conveyor and into waiting bins.

For its first a year, the belt had been powered from either the 240 vac grid mains (the utility grid to Americans), using a long flex (a flexible round cord), or with a portable 1 kW gasoline generator. The final drive was a 370 watt (« HP) star-wound motor with a 1:36 reduction gear pulling up to 1.5 amps. There was a Siemens MicroMaster NN37 drive controller in series with the supply. This rather clever item allowed not only a smooth motor start-up under load but a variable conveyor speed, adjustable with a user-set knob.

Bright Idea

Despite the winter conditions of the Scottish surroundings, a bright idea came to us over the Christmas turkey to apply some renewable energy to the Waste Reclamator. This would not only enhance its appeal as an attraction but also improve its environmentally benign credentials. I based the design on my previous stationary PV systems. I wanted to not only provide an on-board inverter to eliminate a generator on remote sites, but to also charge the batteries during storage, traveling and whilst operating.

First we had to decide where to mount the PVs. My first preference was to create a new framework over the trailer to make a horizontal PV roof which would happily charge no matter which way the trailer was parked. However, the clearance required for people to work underneath on the conveyor would have meant a very high structure which would not fit in the Reclamator's garage. The thin trailer sides were not strong enough to hold the PVs while traveling. This left us no option besides a removable array.

BP Solar Donation

At this stage BP Solar generously donated twelve BP160 65 Watt framed modules, which seemed like the maximum number for a movable array. To ease the constant re-making of the array at each site, sets of four modules were bolted to 50 mm (2 inch) aluminum U-channel. We had three sections in all, each weighing 35 kg (77 pounds) just light enough for one person to lift.

The weight of arrays was taken by the trailer bed, using galvanized 40 mm (1.6 inch) steel tube. The removable subarrays pivot to allow angle adjustment at each site.

Heavy Problems

The challenges of designing for a mobile PV system were now becoming clearer. Not only did the array need to be easy to dismantle and store on the trailer, but the trailer offered no natural protection for the equipment. This was quite an issue considering the inevitable road salt spray behind a towing vehicle. But the biggest hurdle was the accumulating weight of gear. The location of the conveyor on the trailer bed meant the weight distribution was already badly skewed to one side, and the battery location had not yet been chosen. Our first tasks became to upgrade the suspension, add close-coupled tyres, and a hitch with up to 3500 kg (7716 pound) capacity.

A Tight Fit for the Batteries

The 300 kg (661 pounds) of lead-acid batteries had to be slung under the trailer bed well away from the proposed inverter location, and all of the weight had to be balanced. Flooded cells were out of the question because of ground clearance and maintenance issues, so sealed-gel batteries were chosen. We purchased used 6 Volt DC cells from a telecomm project, with a capacity of 100 Amp-hour at a 10 hour rate. They are entirely cased in hard yellow plastic with threaded M6 posts. Two rows of four were laid on their sides so that all interconnects would be accessible.

Below: The Reclamator power panel showing inverter, charge controller, AC breaker and MCB, and shunt. The back of the E-Meter can be seen in the folded down door. At right are the three plugs for the PVs.

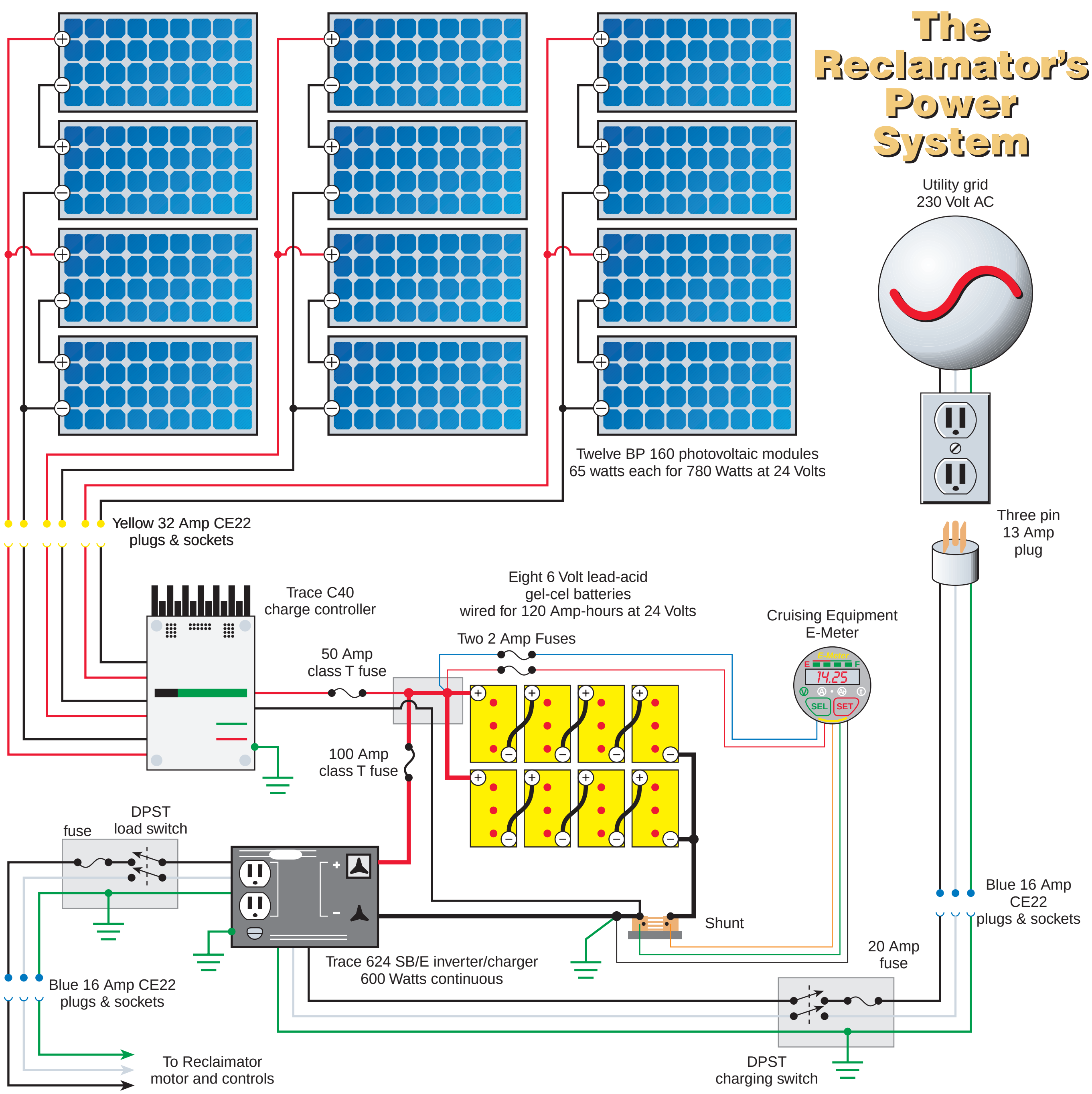
Above: The feed end of the conveyor belt. Phil Evans shows the inside of the opened power panel.

A battery case was constructed from welded angle steel and 25 mm (1 inch) exterior plywood. One side was cased in perspex (trade name for a type of clear acrylic sheet) to allow the public to see the wiring. A 160 Amp fuse was bolted to the positive terminal to protect against a short between the inverter and the battery bank. All cables terminated with crimped terminal ends, with wing nuts on the battery posts. Two long bolts came through the plywood of the box one for positive and one for negative to allow easy removal of the main connections. Then the battery case could be lifted on a hydraulic jack as one unit without any cables attached and bolted to the trailer chassis.

System Components

This battery layout worked well for the 24 Volt system voltage (resulting in a total 100 AH capacity to 50% discharge). It also suited the PVs and the choice of a Trace 624/SB/E for the inverter/charger. A Trace C40 served as the PV charge regulator and an E-meter was used for monitoring the system. The harsh environment dictated a high-integrity lockable IP65 steel cabinet for this equipment. Two pull-out T-class fuses (50 Amp and 100 Amp respectively for the PV array and battery) were bolted to the sides of this as emergency disconnects. Three yellow 32 Amp CE22 sockets to plug in the arrays and a blue 16 Amp CE22 socket for mains battery charging were bolted to the other side. Finally another blue socket was externally mounted as the 230 vac inverter output, via internal 5 amp RCDs.

The battery cables came into the bottom of the cabinet through steel bushings penetrating both the cabinet and trailer chassis. We were concerned about the possible heat build-up in such a sealed cabinet, but the large



metal surfaces were likely to dissipate the heat. The Trace inverter was given extra lower supports to protect it from road vibration. It may be worth noting that here in Europe, a gradual harmonization of voltages is taking place such that the UK 240 vac is being lowered to 230 vac, so this E version of the Trace is set at the lower voltage.

Grounded

The principal hardware used is undoubtedly familiar to *Home Power* readers. But spare a thought for how this system could be grounded. In particular, should the inverter neutral be tied to the chassis/battery negative and the PV negative and frame? Bear in mind that the grid mains might also be connected at times. At first the neutral was linked to the earth ("ground" to Americans) terminal in the 240 vac distribution/disconnect box, which is common practice in portable generators in the UK. This earth terminal is linked to the chassis and both negatives. However, this would trip the obligatory RCD earth protector when charging the batteries via the grid mains. So the link was removed and the neutral only becomes linked to earth by the utility at its sub-station. A future solution for this may be a triple pole changeover switch on the charging circuit. The UK regulations covering low voltage systems are not as well defined as in the USA NEC code, especially for portable PV generators. Strictly speaking, a copper grounding rod should be used at each site and all extraneous metal parts in the system linked to this point, which is a problem on pavement.

Cable Notes

The round trip distance from the furthest PV module to the C40 regulator was measured as 16 meters (52 feet), and we used 10 mm square (between 6 and 8 AWG) stranded conductors. All three flexes were cut to equal lengths to balance the arrays. However this was a tight fit into the gland (a rubber seal) cut into the box at the back of the BP160. The final drive motor was theoretically rated to draw a maximum of 1.5 amps at 240 vac which meant a possible 15 Amps on the DC side over the 10 meter (33 foot) round trip to the inverter. This meant that two lengths of 35 mm square (2 AWG) for each polarity should be ample. Imagine my horror when I connected the clamp-meter of my Fluke 123 oscilloscope and saw peak currents of 10 amps on the ac side!

Further analysis revealed the reason for this. The clever Siemens drive controller was in fact causing problems with the volt-current phase relationship. This was not surprising, as it is principally a large set of capacitors powering an inductive load. Amazingly, the ac side was happily at 1 RMS amps (full conveyor speed), 287 peak volts, 228 RMS volts. This compared to 326 peak volts and 235 RMS volts when using the grid mains, indicating the flat top characteristic of modified sine wave voltage curve. Measuring the DC side indicated that the Trace inverter was coping admirably with this strange load, with peak current at 18 amps within each 10 millisecond cycle (equivalent to 50 Hz on the ac side), and 10 RMS amps.

Reclamator PV Upgrade Costs

Description of Materials	*Cost in £*
Twelve PV BP160 modules	Donated
Freight	4500
Steel galvanized subarray	423
Trailer wheels and hitch	435
Trace 624/E/SB	470
Trace C40, T-class fuses, E-Meter	490
Plugs, sockets, aluminum, fixings	250
Sundry	100
Eight telecomm batteries, box, cables, load center, ac distribution & charging	811
Total	7479

Above: Phil Evans (L) and author Chris Laughton (R) in front of the donated PV array.

Having already commissioned the battery and inverter, it was time to test the PVs. With the sun gloriously beaming in the June sky, I slipped each array plug into the sockets. Watching the E-meter, I saw a very pleasant 32 DC Amps flowing into the batteries causing the green *Full* lamp to start flashing in no time.

One Year Later Problems

The first reported problems came about 8 months after the owners started using the solar-powered system. The inverter was occasionally cutting out, requiring a manual restart of the Trace. Eventually the problem became worse and we had done all we could over the phone. So it was arranged to take the Reclamator out of service for a few days for me to give it a thorough inspection. The battery under no load was showing 24.6 volts, but this quickly dropped to 23.2 volts under load, and the inverter was then switching off as part of its protection circuitry. No restart was possible until ten minutes had passed.

A problem with the batteries or cables certainly seemed likely, and yet the E-meter (with an historical recording function) indicated a 82% charging efficiency, much higher than one would expect for the abysmal battery voltages. All was explained by the next readings of the E-meter. The charge/discharge cycles totaled only thirteen in twelve months of use, and the deepest discharge was 71%. It turned out that the owners had never charged the batteries from the grid and only used a third of the PV array at the best of times, even in the depth of winter. This guaranteed the destruction of the battery! The high efficiency figure was because the E-meter will only re-calculate when the batteries become fully charged.

Cracked Batteries

The voltage of each individual 6 Volt battery was recorded under maximum load and charge, which revealed two particularly poor batteries. We were not surprised when their removal revealed split cases with gel peeking out of the cracks! With these replaced and an overnight charge from the grid mains, the battery under no load was starting at 25.2 volts and dropping to 24.3 volts under maximum load. The final charge setting for the Trace inverter was left at 27.0 volts. The C40 was set for 27.6 volts for the bulk charge and 26.4 volts for the float charge.

When the owners were further challenged over the battery abuse, they claimed that the E-meter fuel gauge and time-to-run feature never indicated a problem. This is a good lesson: These indicators are misleading unless the battery is regularly brought to a full state of charge to allow the E-meter to recalculate. The owners also reported that they rarely used the full 12 module array due to the inconvenience, which shows the practical limitations of removable arrays.

A secondary problem was then addressed regarding the auto-search facility of the Trace inverter. Originally this was left in a medium search mode, which became energized when the conveyor was switched on. For safety reasons, this switching was controlled by a contactor by the original builders of the Reclamator. However, the owners reported that they could feel the contactor points bounce when using the inverter power, and that the coil would then slowly “suck in” allowing full power to pass. Fortunately, the bouncing turned out to be the pulses from the auto-search circuitry. By defeating this and manually switching the inverter to full output, the bouncing disappeared.

The Reclamator continues to reduce the waste put into landfill sites and brings the idea of solar power to even more people. Technically, it was quite a challenge to design and engaged the thoughts of several solar engineers. Given the severe environment, the equipment has fared well. And the owners no longer hire a generator this alone is a reason to celebrate.

Access

Author: Chris Laughton, The Solar Design Company, 57 Wood Lane, Greasby, Wirral, L49 2PU, England
UK +44 (0)151 606 0207
Fax: UK +44 (0)7070 731 369
chris@solar-design.demon.co.uk
Web: www.solar-design.demon.co.uk/

Reclamator Owners: Network Recycling, 10-12 Picton Street, Bristol, BS6 5QA, England
UK +44 (0)117 942 2271
Fax: UK +44 (0)117 942 0164

Photovoltaics: BP Solar, PO Box 191, Sunbury-on-Thames, TYW16 7XA, England
UK +44 (0)1932 779543 • Fax: UK +44 (0)1932 762686
Web: www.bp.com/bpsolar/index.html

Battery and cable supplies and workshop: Solar Sense, The Environment Center, Pier St., Swansea, SA1 1RY, England • UK +44 (0)1792 371690
Fax: UK +44 (0)1792 371390

Trace supplies and workshop: Wind and Sun, Humber Marsh, Leominster, HR6 0NE, England
UK +44 (0)1568 760671 • Fax: UK +44 (0)1668 760484

Technical advice: SunDog, Fell Cottage, Matterdale End, Penrith, Cumbria, CA11 0LF, England
UK +44 (0)17684 82282 • Fax: UK +44 (0)17684 82600
ali.ross@dial.pipex.com