Nepal PV Upgrade

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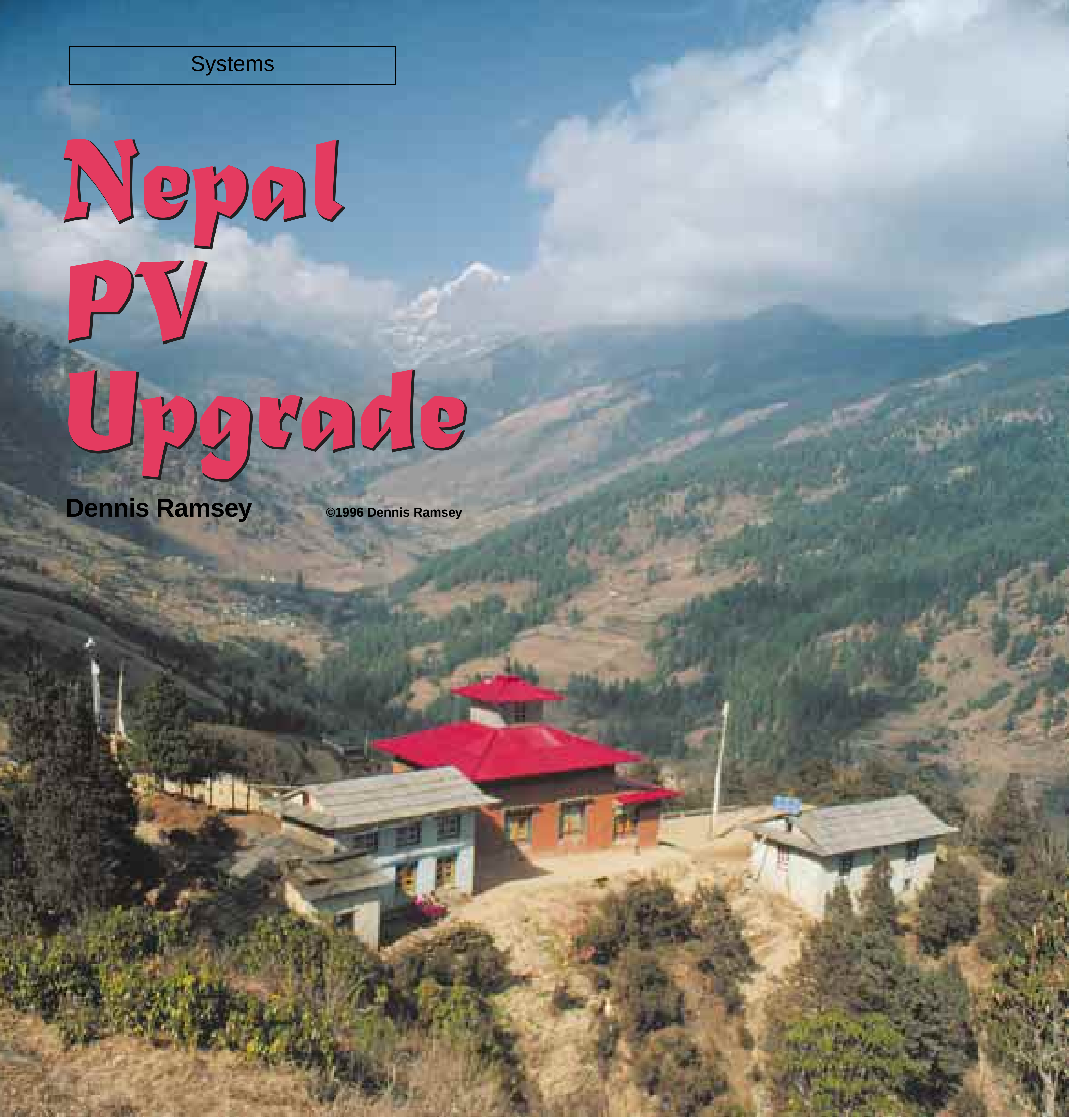

Many Home Power readers followed the cover story in Home Power #45 of my PV lighting installations in two remote Nepal monasteries. That was over a year and a half ago. Since then, Richard and Karen Perez of Home Power donated a third PV module to Pungmoche, so I decided to donate a third one to Tumbuk. Why waste time! Besides, in the traditional Buddhist communities here, it would be a faux pas to improve one system and not the other.

This was my fifth trip to the Junbesi valley in the two and a half years since I did the first installation at Tumbuk. Whenever I'm there I make the rounds of all the PV installations in the area. There's Hillary School with two 35 Watt modules, a UHF radiotelephone system with one module, one private home, and three monasteries that all have PV systems. Even in the most remote parts of this world, PV is catching on.

Above: Tumbuk monks enjoy tea and PV.

Journey Begins

The journey began in mid-November, 1995. I boxed and shipped ahead two more Solarex MSX-50 PV modules and two dozen more Enertron Quad compact fluorescent lights. The plan was to enlarge the arrays of both monasteries by half. I thought I would simply enlarge the array frames I had constructed in 1994 to accommodate a third module each. It seemed pretty simple.

My plan was to do the welding in the field. I flew myself and the gear to Phaplu, Solu Khumbu, then hiked up to both monasteries and got the frames down. We strapped the modules (now three) to the roofs by stringing 12 gauge house wire through the frame holes and wrapping it around nails in the roof boards. We left it that way until I finished modifying the frames. The year before when I visited, I had seen a lot of welded angle-iron window frames and roof joists around the township of Solari. I had assumed, wrongly, that there was a welding shop nearby, since this town boasts a very well-managed Swiss hydro-generator and its own mini-grid. I located a modern hi-tech welding machine with flux rods, which was a very lucky find in the remote mountains. I was lucky enough to find the arc welder, but the area is remote enough that I could not find the angle iron I needed. Finally, I had to take the frames back to Kathmandu by helicopter and do the work there.

Auspicious Timing

Because it was so late in the year and all airports in the mountains were scheduled to close soon for the winter, I opted to leave for India until February. In February, I was waiting in Kathmandu to catch the first flight back to Phaplu airport after winter. My situation was complicated because the frames were now too big to fit into the cargo door of a fixed-wing aircraft. They had to go by helicopter. Finding out which companies are flying which days is not easy. There are several private companies, and their schedules are unpredictable. Their existence is also a bit sketchy from week to week, depending on whether or not they've smashed their aircraft.

I had been told by one company that a Khumbu businessman had chartered an entire Sikorsky helicopter to fly some goods into Phaplu—exactly where I needed to go. I was told that the helicopter was totally jammed, but that if I showed up early in the morning at the airport with frames in hand, he would probably take them. This would free me to go by any aircraft available, so I took the frames to the airport the next morning. He was a very nice guy, and gladly took the frames.

As I was chatting with him, Eberhard Berg came up and tapped me on the shoulder. We both shouted our surprise. Eberhard and his wife Vrenie, are the Swiss anthropologists who originally donated the PV equipment for Pungmoche. I had been sad that they had finished their research and left Nepal last year. I didn't know if I would ever see them again, and they had never actually seen the lights on at Pungmoche! Coincidentally, Eberhard was on that day's fixed-wing flight to Phaplu! As we talked before his flight, it was

Above: Mounting the new module at the Pungmoche Buddhist Monastery.

clear that he wouldn't stay long in the valley. Even if I were able to catch a flight to Phaplu in a few days, Eberhard would already be out of the area. Finally we said a poignant goodbye as he passed through the security curtain and went to his gate.

I wandered over to the enormous pile of goods going by helicopter, and began chatting with old Sherpa and Tibetan friends. They told me they had found space on today's flight for me! I was desperate to go, but I didn't have my rucksack prepared. They said I had about 30 minutes to get it together. I bought my ticket immediately, then bolted for the door to grab a taxi to rush home.

As soon as I hit my front door ten minutes later, I ran through the house upstairs and down, throwing things at my rucksack. I had ten minutes to pack. I forgot food, towel, water filter, and my medications, but managed to bring all the right tools and spare parts. I arrived at the airport and shot through the curtain hoping to find Eberhard, but his plane had left. If there were too much lag time between our flights, I wouldn't even see him in Phaplu or for many days, if then. Sure enough, when we finally reached Phaplu in the Sikorsky helicopter, Eberhard was long gone. I hired my porters for the trek to Junbesi, and went into a lodge to eat lunch. I was bummed-out, in spite of the day's good luck.

I couldn't even focus on lunch, and afterwards went into the toilet out back to contemplate the rest of the day. I grabbed the door knob to leave, just as someone on the outside grabbed the knob to enter. In unison we swung the door open. I was nose to nose with Eberhard! The essence of auspicious timing!

We walked for four hours together, then separated to go to two different monasteries. We agreed to meet in three days to go to Pungmoche. It would be Eberhard's first visit since May 1994, when we laid wire there together for six days. He and Vrenie had not been back to Pungmoche since then. They had to leave before the work was finished, while I stayed to install the array and battery bank.

Cultural History of the Tumbuk PV System

In the meantime, I hiked up to Tumbuk Monastery at the opposite end of the valley. I discovered some interesting things. Apparently, as soon as the system was up and running (150 watts of lighting), and with a full battery bank of 400 Ampere-hours, the monks left all the lights blazing—every night. It took only a short time before the batteries went flat and sent the system into

Below: Ngawang Zimba is pleased with his newly enlarged array.

Low Voltage Disconnect (LVD). At that point, they began to drain the batteries flat every day after the system reached reconnect voltage, cycling 20 to 30 Ampere-hours in and out of the battery daily. This went on every day for many months. The batteries never came up to full voltage or equalized. In effect, the battery bank idled at about 20% state of charge for at least nine months. I realized that it was only the monks' experience with the LVD circuit that caused them to physically understand the limits of the volume of energy they had at their disposal. Once the first 400 Ampere-hours were gone they couldn't leave the lights on all night. They had to learn to conserve, if they wanted lights at all. And it was also the LVD circuit that saved the batteries from being destroyed altogether. Without the LVD in the controller (the cut-off is 11.5 Volts), the inverter (with a low voltage cut-off at 10.5 Volts) would have functioned as the de facto LVD. The bank would have cycled even lower in its range and the batteries would have been wrecked.

So the question became, "How to help them conserve?" I brought Tumbuk and Pungmoche both a fresh dozen Enertron 9 watt Quad CF lights (they're still $10), and used them to replace all of Topkay's larger lights in the

Below: Dennis explains PV wiring.

Above: Ngawang Zimba and Eberhard Berg.

Tumbuk complex. We were able to reduce consumption by 25% by lowering the bulb wattage. I also added a third 50 Watt PV module, increasing their energy input by 50%. And, I added a Dura-Pulse battery conditioner to improve the health of the bank. When I left Tumbuk in mid-February 1996, the battery was hovering close to full charge for the first time in two years!

I concluded that we need smarter controllers, even if consumers had to wait more than one day to recharge the system! But hey, this is the truth! People have difficulty controlling their consumption habits, and the planet shows it. It's true of everyone—me, you, and lamas in remote monasteries. If the power is there to be consumed, and if it's "free", it gets used. This is why there are no second-hand stores in the Third World—nothing that is there as a resource goes unused. This applies to shoes, dishes, and energy.

The people I provided with this electricity have no history of "surplus and how to manage it" like we do in the West. They have a history of "needs and how to manage them," vis-a-vis a very limited resource base. These are quite different cultural experiences and they need different charge controllers. This is true especially for Third World applications, where the users are not technically oriented. We need controllers that take over when the system is being over-used.

The brain of the system must effectively control energy consumption and run an equalization charge regularly, or there are going to be a lot of dead batteries to recycle. In small countries that have no recycling facilities it wouldn't be right to ruin batteries with mis-adjusted charge controllers. I must admit that part of the

Above: Tumbuk Monastery and its PV array.

problem is design error on my part. I designed a tightly budgeted system based on nominal component ratings. I am more aware now that the charge controller has so much to do with the overall health of the batteries. Comparing the controls of the Tumbuk and Pungmoche systems is a good example. These systems are identical except for the charge controller.

Tumbuk has an SCI 12 Volt, 8 Ampere controller with LVD. Factory set points are: LVD at 11.5 Volts, reconnect at 13.5 Volts, and high voltage PV cut-off is at 14.3 Volts. Pungmoche's controller, by contrast, is an SCI 12 Volt, 16 Ampere model without LVD, and with a trim pot to set the high cut-off. LVD is done with an SCI Battery Saver with trim pots for LVD and reconnect voltages. My settings are LVD at 12.5 Volts, reconnect at 13.5 Volts, and high cut-off at 14.8 Volts. If you can wade through that you see that Pungmoche's battery bank is cycling higher than Tumbuk's. It also comes up to an equalization charge when it reaches full.

The pattern of use also has a big impact on battery health. Pungmoche is really a seasonal school so there are long periods when there is not much of a load. But Tumbuk is primarily a residential monastery, permanent home for at least four people. Tumbuk has deeper battery cycling, a heavier average load, and no chance to come to full charge. Any reasonable amount of sun will bring the voltage up to 13.5 Volts, and the controller then reconnects inverter to battery. All of the day's energy is burned-off that night, and the system goes again into LVD. This cycle can go on and on if nothing prevents it.

Technical Concerns

After using and troubleshooting these systems, I have technical concerns about the equipment I am using. The SCI charge controller seems to have an important design flaw. The low voltage disconnect load output is undersized. When a 250 watt inverter is maxed, this is 2 amperes on the 120 vac side, but 20 Amperes on the DC side. The SCI controller's LVD circuit is rated at only half this amount—10 Amperes! This means that the SCI's LVD circuit is only capable of handling about 120 Watts of power. In the installation at Tumbuk, this wattage is almost exactly what they use nightly, so there isn't a problem. I am concerned about what will happen if they use more lights. But across the valley at Pungmoche, there are 23 lights on an identical inverter, and they often have more than half of them on. As fate would have it, I didn't install the same SCI controller at Pungmoche, but a non-LVD SCI model, with a separate SCI Battery Saver. The battery saver unit has a 20 Ampere LVD circuit, that saves Pungmoche from inexplicable shut-downs (if I had installed a controller like Tumbuk's). But I have problems with this particular design parameter on SCI's part. Their 8 and 12 Ampere charge controllers both have a 10 Ampere LVD circuit. It would seem reasonable to assume that a user of a 12 Ampere PV charge controller would want to run more than a 120 Watt load on the LVD side. It makes good sense to me that if you reckon from the maximum amperage on the input side, which is 12 Amperes of array power, going to the batteries at a planetary average of four hours a day, this equals 575 Watt-hours average for a day. An average planetary evening (defined as the time between when people come indoors and when they retire) is also about four hours. 575 Watt-hours of daily input divided over 4 hours of evening usage, is 144 Watts per average hour, and equals at least 12 Amperes DC of load at any given time.

I also had a potentially severe problem with the Dura-Pulse units I installed in three monasteries. The units supplied to me from the factory were not the units I had ordered. Two of the three were mis-adjusted, and would have ruined other equipment if Greg Holder of Alternate Means had not caught the problem. I'm wondering how many other users had wrong units supplied to them. In my case, faulty units could potentially destroy a lot of work at a remote site, and this would have been a hardship for me as well as the monasteries. I had to open the units' enclosures and change several internal pins in order to use these at my voltage. A less savvy consumer would not have noticed this, and might also not have noticed that their system had a long term problem. This could give pulse technology a bad rep!

Learning Curve

I learned a whole lot about reality versus abstract design. There seems to be confusion about what's real versus what's nominal. For instance, if we figure all equipment to be functioning at its rated capacities (that's nominal), we are working with an abstraction that is not true in the field (that's reality). Nominal ratings are only true in controlled circumstances in testing labs. These ratings were created primarily, I think, so that consumers and manufacturers could compare one product with another in order to assess relative value. So, nominal ratings are a bit like a diamond in the rough—some setting and fine tuning is necessary before we get something we can recognize.

What led me to begin thinking in these terms was a problem in my systems. If my equipment had simply performed as per its nominal ratings, there would have been no problem. I began to analyse my systems in detail from modules to light bulbs, to try to understand where all the power was going.

I surveyed the wiring and found all to be OK. The only potential source of voltage loss was the 10 gauge type TC wire running from the inverter to the battery bank. The distance is under eight feet and the max current possible through a 250 watt inverter is 20 Amperes, but I doubled the wire with another length of 10 gauge TC. I also installed a small 1.5 Watt, DC fan in the door of the control box to cool the inverter and controller. Since I didn't have a larger controller (the SCI ASC is an 8 Ampere model connected to a 9 Ampere array), I figured it would help if the unit had some air flow.

The real problem was that there was not enough energy, even though the nominal calculations said there should be enough. I started by measuring the exact load. I used my tester between the terminals of the DC switch that feeds the inverter. This turned the inverter on so I could see what its idle current draw actually was. I let it warm up, then turned on lights one at a time, then five at a time, and finally full on. I was able to get a very specific idea of the true load on the battery. Tumbuk uses about 27 Ampere-hours per day to run the lights it needs. With their original two module, 100 Watt PV array, this is about all they got each sunny day. So, they were idling, at whatever voltage or state of charge. The state of charge they descended to was the LVD point. And they stayed there for a long time while the batteries sulfated. It would probably have been wiser to have used a 100 Ampere-hour battery and cycled it harder, rather than a 400 Ampere-hour bank that can never attain a full charge. The original reason for the 400 Ampere-hour battery bank was to give them winter storage capacity. Even though the bank was full when the system was first turned-on, they habitually used more than their daily input. The controls and the users are both unsophisticated, so there was nothing to prevent the battery voltage from devolving to the controllers' lowest factory pre-set.

Above: Author Dennis Ramsey.

I would have been able to get an immediate grasp of array power flow, if I hadn't managed to burn out the 10 Ampere side of my multimeter at this point. But at the same time, this caused me to have to use the hydrometer and voltage side of the tester to do the same thing. This is arguably more accurate for determining state of battery charge anyway. Necessity and lack of proper tools sometimes helps our learning curve by teaching us new tricks. I recognized that the batteries were suffering. Even though the specific gravity was nearly equal between cells, it didn't jibe with what the voltage should have been at that specific gravity. I also could see deep within the cells that crystals were growing around the busses and plate edges. My conclusion was that this damage was caused by the cells sitting in a state of low charge for a long time. The only solution I had at hand was to install the Dura-Pulse, and the third 50 Watt PV module, change the bulbs to a lower wattage, and let it operate for a while. I also counseled the monks every day to please not use any more juice. I'm expecting the battery bank to slowly rise to full charge over time and then stay there, ready for winter.

I eventually was able to conclude that the real problem with the Tumbuk system was not that the equipment wasn't performing at its nominal ratings. It was. The real world problem was a combination of less insolation than originally thought, damaged batteries, and inadequate charge controller set points.

I am happy to report that there was not a single burnt-out ballast or bulb at either monastery in the last year and a half. In fact, there was only one bad ballast amongst the whole lot, and these lights have been used almost daily for two and a half years.

Journey to Pungmoche
I left Tumbuk and journeyed down to the town of Junbesi to rendezvous with Eberhard. We ate an early lunch and then started our slow ascent to Pungmoche. The frame and other gear had been sent ahead by porter. We had only one day to install the new frame. My plane was to leave in two days, and Eberhard had to leave the next day to follow a pilgrimage to the South. We were quite tired when we arrived.

The dogs were beaten back and we were invited into the kitchen for a bowl of soup. It had been snowing off and on for days, and it looked like it would start again. We thought it best to begin immediately. This was not the kind of weather to be standing on top of a sloping metal roof and looking down a hundred foot drop-off.

Ngawang Zimba, the Lama of Pungmoche, had done a very smart thing ten weeks before when I had removed the PV array's frame. He had a carpenter from the neighboring village come and build him a wooden frame for his three module array. It fit just like it should on top of the old swivel base. Ngawang Zimba had been adjusting his array daily all winter long, and with the added module, courtesy of Home Power, his batteries were nearly topped-off. It also helped that the school was closed for the winter and the students sent home to their villages. There hadn't been much consumption over the winter season.

We exchanged the wooden frame for the iron one just as it began to snow. Eberhard and I laid all our assembled tools and components on the stone floor of the courtyard under the eave of the roof. Taking down the array was easy since the roof hadn't gotten slippery yet. Wood is also much lighter than iron. We swapped the modules into the iron frame on the floor of the courtyard, then four of us heaved it gently onto the edge of the roof. We got it to the ridge and three of us tried to lift it and set into its pipe. One pipe inside another pipe should be simple. No way! We stood in the cold drizzle on a slick, sloping roof, turning blue, while trying desperately not to slip off or drop the array. It was heavy, we were tired, and we were stuck.

The carpenter who had made the wooden frame was in the courtyard below, and he saw our plight. He adroitly walked barefoot up the ladder, no hands, swung out over the abyss. He stood on a four inch piece of the tiny window frame under the ridge pole. He lifted the frame almost by himself, and we were able to guide it to its mount. Amidst the shouts and laughter, I could have sworn I heard him make a dirty crack about what's so hard about one pipe inside another pipe.

Since the batteries were in such good shape, I installed a small DC fan in the control box door, a Dura-Pulse for insurance, lowered the bulb wattage, and called it done.

My hope is that these PV systems will last a long, long time. Provided the batteries don't go bad due to under charging, they just might. It helped tremendously to add a third PV module and a Dura-Pulse to each system. I must say that Trace now makes a charge controller (the C12) with a brain, that is user adjustable over a wide range, and has auto equalization. This should solve most of my problems.

Cheers from Nepal!

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