SOLAR POWERED INFORMATION AND COMMUNICATION TECHNOLOGIES IN DEEP RURAL COMMUNITIES

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ABSTRACT

For the past three years the authors have brought solar powered Information and Communication Technology (ICT) to deep rural villages in remote parts of Africa, Latin America and Asia. ICT solutions -- computers and internet connections, by satellite or long distance wireless links -- require the reliable electricity that renewable energy can provide where fuels are expensive and logistically difficult to secure. Given the severe demands of such environments, the authors have developed methodologies and technologies to meet the need for sound, reliable performance of such systems far from established service centers.

1. REMOTE COMMUNITY CONDITIONS
Technological and Logistic Challenges

When traveling in the remotest parts of the world, at times one is struck by the overwhelming acceptance of modern technologies. Some technologies are abundant because of their simplicity, others defy the imagination by their complexity. Some technologies seem to always work. Others are famous for breaking down. We have all been to an event where the PA system didn't work. Some technology is sufficiently robust that one can limp along on a quick fix, while other technology requires extraordinary care where replacements or repair services are not readily at hand. For those who live in remote parts of the world, a burned out computer chip can mean going for weeks without a tool or service that has become important to the quality of life.

The extraordinary demands that challenge the effective use of advanced technologies in remote communities include severe environmental conditions such as high humidity and heat, computer bugs of the organic variety, or difficult logistics such as 8 hours on dirt roads to the nearest fuel station or telephone line, islands with limited docking facilities, essentially bucket-brigade handling of goods and equipment, and a dearth of basic tools and supplies (not a single spare light bulb in a village, the only hammer in the village has a broken handle, a vendor brings ethernet connectors and a crimping tool but no wire, to name a few). Beyond environmental and logistic constraints, the shortage of technically trained personnel also presents challenges for remote communities.

2. THE TECHNOLOGY CHAIN
The “Cold Chain” Analogy Suggests a “Technology Chain”

In rural development, the term "cold chain" has great significance. If a vaccine destined for a remote village is compromised by overheating at any stage in transit or in storage, it becomes worthless or even dangerous. The record-keeping of temperature control is the "cold chain." In like fashion, we can talk about a "technology chain" -- the critical links to keep a machine running or to maintain a service.

If any part of an ordinary bicycle breaks down, it is usually quite visible. A broken chain is obvious, and, with simple hand tools and a few spare links, it can be quickly repaired. An electric bicycle, on the other hand, has many invisible parts. With its wires, switches, fuses, electronics, motor windings and brushes, an electric bicycle requires know-how and spare parts to remain functional. In like manner, each technology comes with its unique maintenance characteristics.

In designing and implementing a complex system for remote application, technology chain management becomes an important discipline. Which parts can be out of service while the system continues to function, even if crippled in some fashion? Which critical components can be made redundant? What back-up procedures can be used to preserve services or data in the event of component failure? To succeed, one must clearly define all steps and components in terms of functionality or service performance; one must identify vulnerabilities, contrast these vulnerabilities with natural redundancies, and/or build redundancies into the system.

With this technology chain discipline in place, a system can be build with fewer failures and shorter down times. Considering our own field experience in such demanding conditions, we have been motivated to develop technical training, fault-tolerant hardware, disciplined methodologies and enduring support systems:

- To avoid long delays during installation for shipment of missing supplies, advanced *logistics* and thorough *documentation* are critical.
- To simplify repair of failed equipment in the absence of trained personnel, we have developed a modular *"plug-and-play" electrical interface*.
- To assure that equipment is properly maintained and to identify problems before they become critical, we have developed an on-line *remote energy monitoring* system
- We have adapted "*community outreach*" procedures to build human capacity – creating a technical support base over the course of time. It is important to identify training requirements, develop diagnostic procedures, conduct trainings in repair procedures, and establish maintenance commitments.

These points are considered in more detail in the discussion which follows.

3. <u>LOGISTICS AND DOCUMENTATION</u>
   Bring Everything You Will Need.

Confronted with challenging conditions in remote areas, a field crew finds it reassuring to be supported by provisioners who seem to think of everything. For the backup logistics team to reach such proficiency requires experience and close cooperation between the different parts of an organization. Purchasing systems, complete checklists, and elaborate documentation (assuming little expertise on the part of the installation crew) are obvious but essential methodologies for completing a project located where one can't run to a hardware store if a part is missing.

4. <u>"PLUG-AND-PLAY" POWER HUB</u>
   Modularity is Mandatory.

Given the complexity of advanced energy systems and the limited technical skills available in these remote environments, anticipating eventual failure of electronic components is critical. With very limited diagnostic tools or specialized small parts or tools on hand, repairs can be challenging or impossible. If it were possible to swap failed equipment readily, support and maintenance could be greatly expedited. While preparing for one of our upcoming projects, a solution became evident. (See Figs. 1 and 2.)

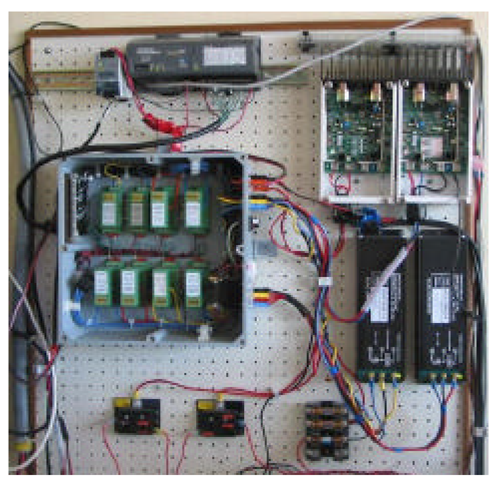

Fig. 1

Power Hub with Energy System Components

In the context of our work, it has been appropriate to look for synergies between various subsystem designs. We found it cost-effective to place the complex energy monitoring equipment into a single concentration of sensors in one box. Once that requirement was defined, it became straightforward to incorporate a set of modular connectors to plug each component into this box ("power hub"). This then created the possibility of swapping out damaged equipment with new equipment by simply unplugging color-coded, geometrically unique connectors and inserting a replacement. This could be an inverter, charge controller, battery pack or dc/dc converter. Each such device or subsystem is prewired with its unique connector in a central support station. While such connectors (typically high-amperage) are slightly more expensive than direct wiring, a single trip by a technician involving flight on an airplane can be an order of magnitude more costly. The added cost of a few connectors is more than amply justified by better service, reduced maintenance expenses and fewer logistical hassles.

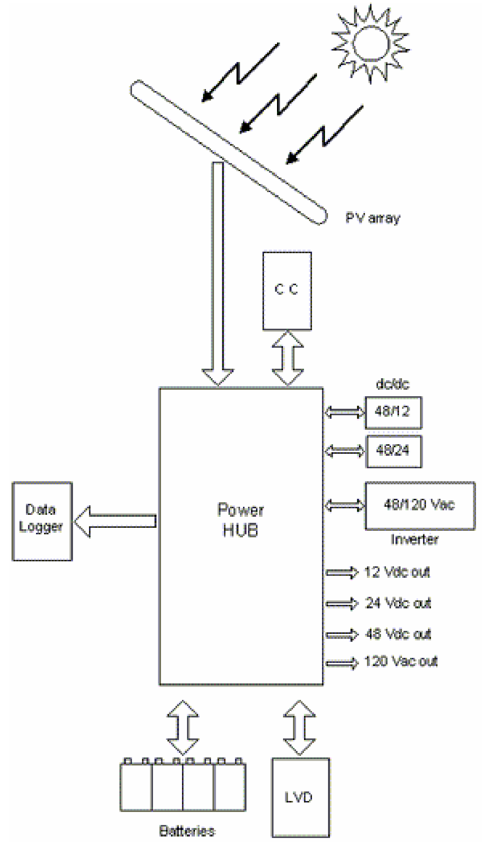

_Fig. 2

Power Hub Schematic

5. <u>ON-LINE REMOTE MONITORING</u>
The Case for Monitoring Battery Health

Looking ahead to long term maintenance issues, one of the most vulnerable subsystems in remote solar applications is the battery bank. Once even a single battery in a chain is compromised (for example, by poor maintenance or overcharging), performance can degrade quickly. If a mechanism exists to monitor battery conditions, it will be possible to respond quickly and restore equipment to appropriate standards before complete failure occurs. Because our solar systems are installed for the purpose of powering school computer labs and internet connections, it is possible to tap into this data link to transmit electrical and energy data to a centralized server. Data from this system can then be displayed on the World Wide Web. When malfunctions or exceptions occur, customized alerts can be e-mailed to on-site staff, in-country support and/or an external international support center. (See Figs 3.)

Fig. 3
Battery Voltage
PV voltage: Upper to Lower
Battery voltage: Lower to Upper

6. <u>COMMUNITY OUTREACH AND CAPACITY BUILDING</u>
City Cousins and Country Cousins Meet.

As part of our original plan for capacity building for our telecenter project in Porvenir, a deep rural community in the Amazon region of

Bolivia, we recruited three high school students from Colegio Nacional Florida, the oldest secondary school in the city of Santa Cruz de la Sierra. While waiting for imported solar equipment and computers to clear customs, we trained these students in a computer lab at Nur University. Then these three high school students accompanied us to the village, teaching their peers about solar energy and computer technology.

In the two years since the micro-solar installation, one of these students, Javier Leon, finished his senior year of high school and his first year of university on scholarships provided by Nur University and the SolarQuest® Institute. Recently he went to Porvenir to make repairs and upgrade equipment. The demanding character of rural tech support becomes evident upon examining Javier's own account of the service that he performed in January 2003.

JAVIER LEON'S TRIP TO PORVENIR, 11-22 JANUARY 2003

Prior to his travel to Porvenir, Javier prepared a plan.

WORK PLAN:

- Update and maintenance of software
- Make a general check up on the Operating System (Windows 98)
- Solve problems with floppy disk units
- Organize a workshop on maintenance and care of computers.
- Teach the use of some programs.
- Identify problems in the computer center.
- Make electrical system drawings of the computer center.

PROBLEMS ENCOUNTERED

When he arrived in the village, Javier found these problems:

- Floppy disk units in all the computers are completely dirty.
- The network is down.
- A CD ROM unit does not respond.
- A computer monitor was brought to Santa Cruz months back and it hasn't been returned yet.
- The keyboards are dirty.
- The interior of the PC cases are full of dust.
- The PC mice are useless due to the dust.
- Some Office components were erased so it does not work properly.
- Some Hard disks have defective sectors.
- The digital camera does not accept floppy disks.
- The batteries are not responding properly.

TASKS PERFORMED

After meeting with the community to explain the reasons for his visit, Javier did the following:

- Defragmentation of Hard Disk Drives
- Troubleshooting of Windows problems
- Installation of utility software
- Hardware check-up: One Hard Disk is damaged, one CD-ROM is not working.
- Troubleshooting of MS Office. As we did not have access to the network, we had to interchange the information manually, from hard disk to hard disk.
- Complete maintenance of all the computers: mice, keyboards and PC cases cleaning as well as internal components.
- Workshop on maintenance and care of computers with the people of Porvenir
- Workshop on precautions that should be taken before opening a computer and taking apart internal components.
- Warning notices to avoid touching certain components
- We could not do anything with the batteries. They already are worn out, and they do not store energy.

EXCERPT FROM TRIP ACCOUNT

> "... All together we were 11 people traveling. Around 5:00 p.m. the wheel came off the transmission and thus the vehicle became completely useless to continue our trip. Faced with this situation, we joined a group of farming technicians and farmers that were traveling in a pick-up truck which left us about 30 km away from the closest community where we could spend the night. On the other hand, the driver of the car in which we were traveling returned in another pick-up truck to call

> by radio to Santa Cruz and ask for help. After we left the pick-up truck, we walked until 11:30 p.m. Due to fatigue we decided to camp right there, basically in the middle of the road. At 12:00 p.m. the next day, a truck going the same direction gave us a lift. We arrived at the Picaflor community where we spent the night and part of the next day. People from Porvenir, warned by radio about our incidents, sent a light truck to pick us up in Picaflor. We finally arrived at the Community of Porvenir …. "

In this context of remoteness and hardware attrition, it is remarkable that one dedicated student on his own initiative traveled 650 kilometers and provided such incredible service to the community. He arranged his trip, surmounted the challenges of travel in the jungle, ingeniously improvised procedures to recover the functionality of several damaged computers with very limited resources, and returned in good spirits. By all accounts from his mentors at Nur University, he is an exceptional young man who personifies and validates the sponsors' investment in human capacity building.

If we were to respond to maintenance issues by sending professionals from the USA to Bolivia, the cost obviously would be prohibitively expensive in the long term.

Based on Javier's experiences, we have reflected upon the challenges which arise from conditions in remote telecenter applications and continue to evolve our responses to these conditions.

7. CONCLUSION

> "Information is a basic human right and the fundamental foundation for the formation of democratic institutions."
>
> Nelson Mandela

To realize the potential for reliable performance of high technology in remote settings, we have developed a power hub and an online energy monitoring system. These have been in operation under laboratory conditions for over six months, and will be deployed in the field in 2003. Experience gained from earlier projects and ongoing technology development are strengthening the viability of modern tele-communications in deep rural communities.