Report on Philippines BCS Monitoring for Business Model Assessment

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GTC has continued to monitor the performance of the solar battery-charging station in Baclaw, Negros Occidental. The comments below reflect analysis of the data collected from August 2003 to March 2004.

The monitoring data show various positive aspects of the BCS operation in Baclaw:

- Twenty customers made consistent use of the BCS, charging at least once per month, along with two communal batteries used in the barangay hall and the health center. The repeat business suggests that those customers valued the charging service at the offered price.
- An additional 16 users made sporadic visits (1-3 chargings during the monitoring period).
- New customers, outside of the original 25, could join; several did during the period of analysis
- Spaces—"charging slots"—were almost always occupied.

The data also showed various inefficiencies with the BCS model used at the site, including technical, financial, and operational losses:

Technical Losses

- **High charging rates** – Charging batteries one at a time in a single day requires a rate of charging of approximately C/5, assuming an expected resource of five sun-hours. That rate is twice the C/10 that would generally be the recommended maximum beyond initial "bulk charging".
- **High charging voltages** – The BCS had no charge controllers. The lack of high-voltage protection meant that the batteries were often subjected to voltages higher than advisable. While occasional charging voltages above 15V can be useful for equalization, the data show consistent median peak voltages of 15.5V or higher.
- **Poor matching** – The energy available from the BCS on a given day was often not a good match with the energy needed by the connected battery: either too much or too little energy was made available to the battery. Too much means that energy is wasted; too little, less than full charging.
- **Reverse current** – The BCS had no electronic mechanism (a diode, for example) for preventing reverse current, a leakage of energy from the battery back into the array after sundown. That current was up to 0.5A, implying that a battery left connected overnight could lose up to 8-10% of its energy.
- **Bad contacts** – Bad connections between the BCS and the battery could result in losses of more than 50% losses. Two batteries, one well-connected and one poorly connected, with similar starting voltages charged on days with around 5500 Wh/m^2 of insolation in late 2003, for example, received 96 Ah and 40 Ah, respectively. Poor contact can result from operator error (battery clips poorly attached to the battery terminals) or degradation of the clips (rust) or the battery terminals (corrosion build-up).
- **High starting voltages** – Up to 15% of the batteries appeared to arrive with starting voltages above 12V, suggesting that the batteries were already fairly well charged. The high readings were likely, however, related to the bad connections discussed above, not indicative of the true battery state of charge.
- **Defective batteries** – Defective batteries appear to absorb the energy provided by the BCS, but in reality do not retain a charge. The data show, for example, batteries on particular days with ending voltages of 12.73, 12.63, and 12.49—ostensibly full or close to it—dropping to 12.25, 12.15, and 11.73, respectively, when subjected to only minor loads (from the reverse current). Those data indicate much lower actual states of charge, despite absorbing daily charging energy of up to 90 Ah. Batteries may suffer from repeated deep cycling, physical trauma during transport, and the fast and high-voltage charging.

Financial Losses

- **Low utilization factor** – The BCS achieved only a 76% utilization factor, with only 495 charges out of 651 “charging slots” usable/sellable, principally because of frequent multi-day charging of given batteries.
- **High utilization by public batteries** – Twenty percent of the charges—98 out of 495 charges on the three channels—were for barangay hall batteries, which presumably were non revenue-generating. They may also have been used as filler, charged on days when no other batteries had appeared.
- **Additional, from technical losses** – Other technical losses also result in financial losses, with the BCS not capturing the potential revenue (in the case of underutilization of the charging potential by needy batteries) or the customers not getting their money’s worth (in the case of undercharging) and/or being left without their battery for an extra day.

Operational Losses

- **Early pick-up** – Customers would at times collect their batteries early, resulting in incomplete charging and loss of the additional energy from the BCS.
- **Late connection** – Batteries were sometimes connected to the BCS later in the day, as a result of operator error or customer actions (late battery drop-offs). At times the operator would connect the battery but neglect to throw the switch to begin the charging.
- **Leakage from overnight connection** – Batteries left charging overnight would suffer from reverse current, leaking energy back into the module (see Reverse Current, above).
- **Design potential** – The BCS is not being used to its design potential, largely serving a customer base smaller than expected (reaching 20 plus two communal systems, instead of 25).

Additional BCS Performance Analysis

Figure 1 below shows starting and ending battery voltages from a sample two-month period in late 2003. The median starting voltage for the period was 10.4V. More than half of the starting voltages were below 11V, indicating completely discharged batteries; several began below 8V. Many of the higher voltage readings likely resulted from either poor connections or batteries in their second day of charging.

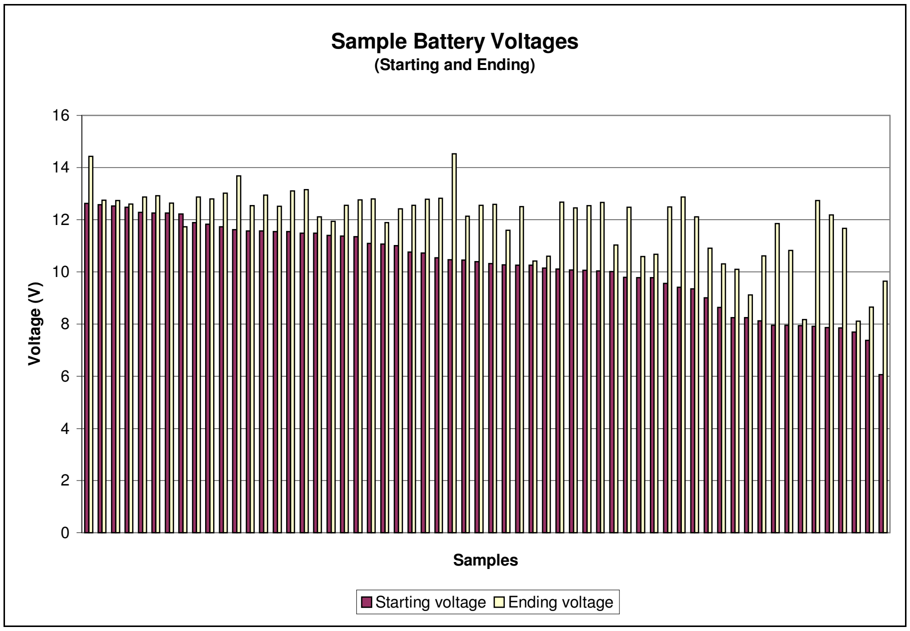

Fig. 1 – Charging data for multiple customers, November to December 2003, by starting voltage

Figure 2 shows sample starting voltages from one customer's battery during the monitoring period. The drop in the starting voltage of a given user's battery over time suggests a degradation in the battery's capacity. Other explanations are also possible, such as that the customer charged his battery less often in the later months, but the data show a consistent pattern of charging 3-5 times per month from November through March (though more in September and October).

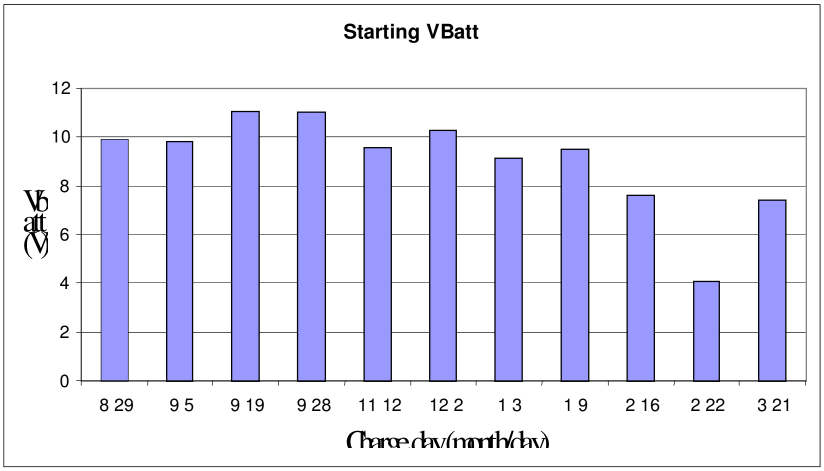

Fig. 2 – Data for one customer ("Turning") from charging on the BCS channel no. 1

Figure 3 shows the frequency of battery charging during the analysis period. The 20 most frequent private customers and two public (barangay hall) batteries had a median frequency of 17 charges over the seven months, slightly more than one charge every two weeks. Several customers averaged about once per week. The additional 16 customers participated very seldom, or dropped out completely during the monitoring period.

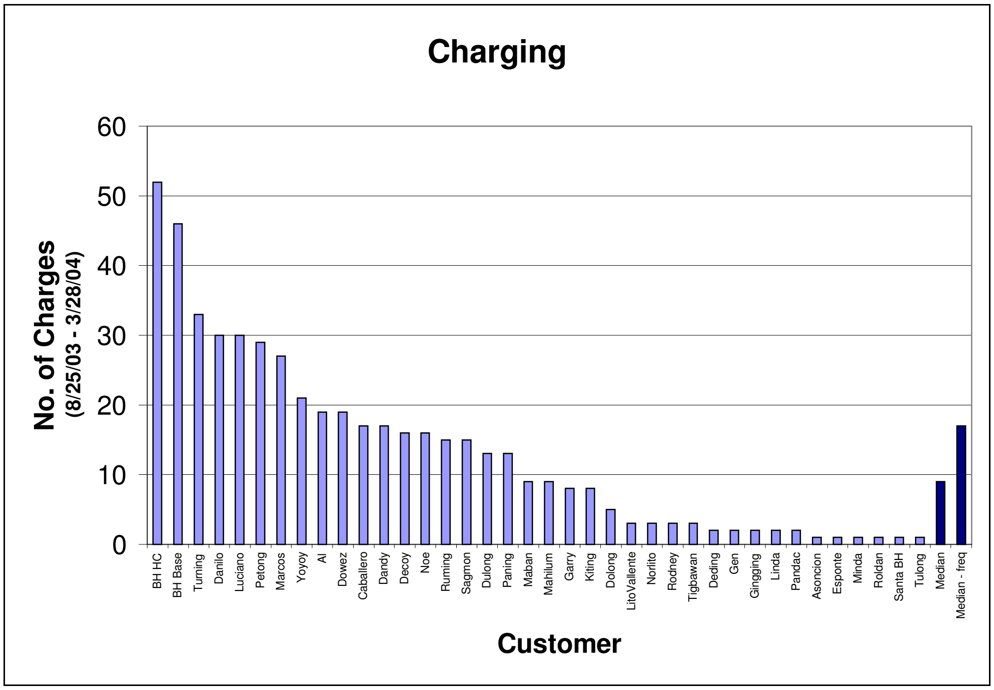

Fig. 3 – Data on customer charging frequency (all three BCS channels)
"Median" and "Median – freq" are the median of the customer base and of the most frequent users, respectively

It is not clear if customers would charge their batteries more often—if they would have the need and ability to pay—if there were no queue (or concerns about having to wait).

Implications and Possible Solutions

Within the existing BCS framework, certain mitigating strategies are possible for most of the sources of loss identified.

Type of Loss	Source	Possible Solution	Comments
Technical	High charging rates	Use larger batteries, with an LVD on the BOS or the battery itself, such that the batteries would discharge only 50%. A BCS design with a C/10 rate would then leave the battery fully charged in 5 hours. Use charge controllers (below).	It may be difficult to keep customer compliant, keep them from bypassing the LVD. Also, larger batteries would be more difficult to carry.
Technical	High charging voltages	Use charge controllers with a multi-stage charging algorithm to provide for bulk charging at low states of charge, but battery protection at higher voltages.	Charge controllers add complexity, representing another potential failure point, though reliable options are available. They also add cost.
Technical	Poor matching	Create auxiliary loads for excess energy, using the BCS to power other loads when no battery is connected. Use smaller, deep-cycle batteries to charge more consistently in a single day and improve portability. Such batteries may be interchangeable, allowing users to drop off an empty one and pick up a full one.	The auxiliary loads (such as small batteries for a mini-BCS market) might be charged only intermittently, not reliably. Smaller batteries would make sense only if extra batteries (or another auxiliary load) could absorb the BCS's excess energy. From the customer perspective, smaller batteries would mean more frequent charging unless the efficiency of the BOS could be improved.
Technical	Reverse current	Use charge controllers (above).	(Above.)
Technical	Bad contacts	The BCS operator could replace the battery clips as necessary, and clean the battery terminals.	The cost of clip replacement is likely to be minor, but would require soldering to ensure a good connection.
Technical	Defective batteries	Test batteries occasionally to identify defective ones. Switch to smaller, deep-cycle batteries (above).	The cost of more frequent battery replacement may be unacceptable.
Financial	Low utilization factor	Reduce multi-day charging with smaller batteries.	(Above.)
Financial	Utilization	Analyze the charging of the public (barangay hall) batteries, to see if they	

		are in need of that level of charging, or being used only as filler loads.	
Operational	Early pick-up	Educate customers about the importance of a full charge. Use auxiliary loads (above).	Customers may still care more about the convenience of picking up at a certain time.
Operational	Late connection	Use auxiliary loads (above).	
Operational	Overnight connection	Use charge controllers (above).	

Technical Alternatives

Other possible solutions extend from considering alternatives to the standard BCS. The chart below contains a comparison of four options with respect to important attributes.

Attribute	BCS	Mini-BCS	50W SHS	Smaller SHS
Safety, convenience (battery hauling)	Least safe (heavy, risk of acid)	Safer (lighter, sealed)	Safest (no battery hauling)	Safest (no battery hauling)
Ease of use	Hardest – battery must be left for charging (requires 2 trips minimum)	Easier – battery can be exchanged (single trip)	Easiest (no battery hauling), though no charging on demand	Easiest (no battery hauling), though no charging on demand
Level of service (amount of energy available)	Medium	Lowest, though investments in efficient BOS could be very cost-effective	Highest	Medium
Energy usage (match between resource and need)	Varies – Batteries ostensibly come only when they are in need of charge	Good – Batteries come only when they are in need of charge (no incentive for early charging because of swap option)	Varies – Well-managed batteries may waste energy at the top end of the charging (that is, not accept more charge when full)	Varies – Well-managed batteries may waste energy at the top end of the charging
Battery treatment (depth of discharge)	Poor – batteries are generally discharged deeply	Poor, but more likely to be deep-cycle and able to withstand the cycling	Potentially good, if users budget well	Potentially good, if users budget well
Economics (cost per customer)	Medium	Potentially lowest cost	Most expensive	Low-medium

Appendix: Notes on Monitoring

GTC made some significant advances in the BCS monitoring work as part of its business modeling, particularly in terms of data collection using SMS (simple message system) in areas where the GSM (Global System for Mobile Communications) signal is weak. GTC demonstrated the potential for collecting and transmitting data where only voice service (no data/fax service) is available. Because of the efforts of staff during a visit to the Baclaw site in January, a local GTC subcontractor now receives data by SMS hourly during the day on the performance of the system over the previous hour. More broadly, this ability increases the geographic range of potential remote monitoring activities in the country with cellular phone service.

The chart below includes some issues that GTC encountered in its monitoring, and some solutions.

Issue	Possible or Actual Solution
Remote data collection via cellular connection (dial-in) was not possible given the weak signal in the Baclaw site.	GTC implemented SMS text messaging of key data (see above). While the practical limitations of the SMS texting resulted in some loss of detail on, for example, end-of-day battery conditions, the advantages of remote collection outweighed those limitations.
Customer information is not completely reliable, with names likely misidentified in the paper tracking.	The monitoring equipment could require a battery code (entered on a keypad or scanned) before operating.
BOS data, which are important for understanding the BCS value proposition, are not captured in the BCS monitoring.	Separate monitoring systems would be needed, though they could be simple ones tracking only consumption information.
Multiple channels presented a challenge to efforts to track particular batteries over time, as batteries could be charged on any of three channels.	GTC monitored the principal challenge, but would be able to use its existing set-up to monitoring key attributes of up to three channels (see below).

Options for monitoring multiple channels include:

Attribute	Setup 1 (now in use)	Setup 2	Setup 3
Channel 1 voltage	x	x	x
Channel 1 current	x	x	x
Radiation	x	x	
Other (temperature, wind speed)	x	x	
Other (temperature, wind speed)	x		
Channel 2 voltage		x	x
Channel 2 current			x
Channel 3 voltage		x	x
Channel 3 current			x

x = included