Picohydro generator

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ABSTRACT

This webpage is about the "PicoHydro Generator" Project from the 2008 International Design for Development Summit (IDDS, http://www.iddsummit.org), organized by Amy Smith of the Massachusetts Institute of Technology (MIT), and others contributors. We propose the use of picoHydro power systems in Guatemala and Honduras to meet rural

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electricity demands, cleanly and efficiently. Specifically we've developed tools that can be used to easily convert a car alternator into an electric generator for a picoHydro system.

Introduction

In many Latin American countries, there is a disparity between the abundance of natural resources and a lack of access to electricity in rural zones -- even more so in isolated mountain villages. Several proposals have been made in an effort to solve this problem (e.g. wind and solar power). Fortunately, mountains in both Honduras and Guatemala have an immense hydropower resource, and so power obtained from streams and rivers is an excellent option for electricity generation.

The Appropriate Infrastructure Development Group (AIDG, http://www.aidg.org) has

designed a simple picoHydro power system in Guatemala. These systems are expected to generate about half a kilowatt of power-- enough to power lights and radios, agricultural processing equipment, and/or charge batteries -- which will be useful to families currently living in isolated mountainous areas without access to the electrical grid. The system consists of an impulse turbine built from PVC piping and a Toyota pickup alternator converted into a generator (which runs at a more suitable rotational speed than the original alternator and doesn't require a current for start-up). The most expensive and difficult-to-build part of these systems is the electrical generator. The generator requires a laminated steel core to which strong magnets are attached. Cutting out laminates for the generator core by hand takes one person three days.

Understanding the Market

- 75% of people in rural Guatemala and 55% of people in rural Honduras live without access to electricity-- therefore the main market is in rural communities where access to electricity is difficult and/or expensive
- The total hydropower potential in Guatemala and Honduras is around 10,000 MW
- In developing economies, increasing access to electricity tends to increase human development (HDI)
- There are picohydro markets in other places...
  - In Vietnam, an estimated 100,000 - 150,000 picohydro systems (100W - 1000W) have been sold according to the World Bank (http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTENERGY/EXTRETOOL
  - Organizations such as HEDON

(http://www.hedon.info/goto.php/CommunityPicoHydroKenya) work on picohydro in Sub-Saharan Africa

The Argument for picoHydro

- MicroHydro power systems require trained technicians for installation and maintenance
- picoHydro systems (less than 5kW capacity) are more appropriate for isolated rural areas
- picoHydro systems can be cheap, easy-to-build, and easy-to-use
- picoHydro systems can be fabricated out of locally available materials

Project Requirements

To develop a simple, low-cost way to convert a Toyota pickup alternator into a generator for use in picoHydro systems in rural Guatemala and Honduras. In order to achieve this goal we developed tooling that could be used to do the conversion efficiently and quickly.

Our target picoHydro system would be able to generate approximately 400 watts of power, enough to provide electricity for light, TV/radio, agricultural processing equipment, etc for a family living in isolated areas of Guatemala, or another country with similar abundant natural water resources.

Ideally all components of the system and necessary tools to build and implement the

system should be available in Guatemala. (In reality it is hard to find high power magnets of the right form-factor in developing countries.)

The system has to be cheap; hence the manufacturing process has to be cheap and not complicated. Predictions of total cost for current AIDG picoHydro system are around $300. We hope a better alternator-->generator manufacturing procedure could decrease that price to around $250.

Design

During the process, we interacted and shared information and ideas with AIDG in Guatemala. We started by converting a Toyota pickup alternator into a generator, replicating the time-consuming process developed by AIDG. This process involved disassembling the alternator and then fabricating and installing a new core. Through this process we learned ways to reduce the manufacturing time and developed tools to make this process easier and faster.

The most time consuming aspect of the current process is making the generator core. AIDG estimates that it takes three days to do the conversion. The core must be made out of laminated sheet metal. The sheet metal is currently cut by hand using tin snips. The laminates are necessary, not only because they prevent eddy currents from forming, but they are also much easier to manufacture in simple workshops than a solid core, which would need to be made with a milling machine. Given the size of the core (1.5 inches in height) and the thickness of the available sheet metal (~1mm) it takes about 40 laminates to build up one core. Each has 12 sides, a center hole, and at least two holes

for bolting the assembly together. The holes are current drilled with a hand drill. It is quite difficult to make all these shapes precisely enough to attach together. It is important for them to be as accurate as possible because any error could cause imbalance in the rotor and therefore forces on the shaft. With an imprecise core, the shaft would fatigue over time.

We developed three tools that help us to cut out this laminate shape in a quick and repeatable manner. The tools are simple. After an investment of about 1-2 days to build these tools, they will save at least 2/3rds of the time necessary to build a generator core, cutting the fabrication down to less than one day.

Three Innovative Tools

Our three tools are simple and relatively easy to build.

1. A template to allow the holes to be punched and centered.

2. A jig that allows the center hole to be drilled.

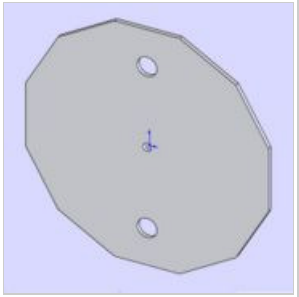
3. A cutting tool made from modified tin snips.

Tool 1: The Template

The template is a precise 2mm thick sheet of steel (twice the thickness of the laminates used to manufacture the core), which is the same shape as the laminates, with the exception that the center hole is smaller. Although we designed our template in CAD and

used a Waterjet to cut it out, it can be manufactured by printing the template shape on a sheet of paper, placing it over the sheet metal, and carefully cutting it out with the available tools.

This template can be clamped to the sheet metal, from which the laminates will be cut, and is used to mark the edges of the laminates, punch the bolt holes, and center punch the shaft hole.



A SolidWorks rendering of the template

Tool 2: The Jig

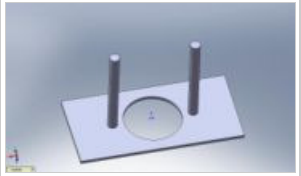
The jig was designed to align the laminates so that the center hole (shaft hole) could be drilled accurately. It was designed so that approximately 5 laminated shapes could fit on it (more could cause the drill bit to jam), using the bolt holes for alignment. Once the laminates are stacked, the hole can be drilled by aligning the center of the bit with the indentation created by the center punch. The circular cut-out in the base of the jig allows the bit to pass through. This jig is particularly important because the most essential aspect of cutting tool (discussed next) is that the center hole is precisely aligned with respect to the cutting blade.

Using the template to trace out the laminate shape

Tool 3: The Cutting Tool

The cutting tool consists of a rectangular metal base, with a center metal pin and the tin snip blades attached both to the base and the

handle. There is also a aluminum angle ruler that slides over the base surface to guarantee the right cutting angles. The ruler can be twisted providing both 30 and 60 degree angles.



A SolidWorks rendering of our prototype jig

Video showing how the cutting tool works (on YouTube): http://www.youtube.com/watch?v=yxomgTxCzGA

Converting an Alternator into a Generator

We would also like to share information on how to convert and alternator into a generator so that others can repeat our process. In this procedure we use the tools that we've detailed above. It's possible to do this without our specialized tools though it will take you much longer if you are doing it by hand. If you have a full machine shop at your disposal you can do the conversion in several hours.

A SolidWorks rendering of our prototype cutting tool

Step 1. Dissemble the alternator fully

- Detach the stator and rotor, using a vice and wooden jigs. (Note: We tried to separate the shaft of the rotor to reuse it but it is not possible with a Toyota pickup alternator.)

Step 2. Buy magnets of appropriate size and buy/machine new shaft to match the dimensions of the original.

- Rare earth magnets can be purchased from KJ Magnets, http://www.kjmagnetics.

The actual cutting tool prototype

Step 3. Build the core. (We found that it took 2 hours to cut out all of the laminates using our tools and the following procedure.)

- Cut square pieces of metal, slightly larger than the desired side of the core (we used 3" x 3"). This can be done by marking the shapes and cutting them by hand, with a band saw, or with a sheet metal cutter.
- Put the template over one of the square metal sheets, and fix it with a clamp.
- Trace the edges on the square metal sheet with a marker.
- Punch the 2 bolt holes using the holes in the template to guide the punch into the right position.
- Center punch the center hole... this will become the shaft hole.
- Repeat the above steps to produce 40 laminates.
- Stack about 5 laminates on the jig and drill the center hole, using the indentation from the center punch for alignment.
- Repeat above step to drill all laminates.
- Use cutting tool to cut the 12 sides of each of the laminates by (1) centering the sheet using the center hole (2) using the aluminum angle ruler to align the cut (30 deg), (3) cutting using the handle, (4) rotating the shape and aligning with the aluminum angle ruler (60 deg), and (5) repeating for all sides.

Step 4. Build set screw assembly.

- Fabricate a small block to attach to the top of the laminates by cutting out holes for the shaft and bolts.
- Drill a hole for a set screw into the side of the block.
- Sand down part of shaft where the set screw will lock the laminate core to the shaft.

Step 5. Assemble the generator

- Put all of the laminates on the shaft and align them so that the bolt holes match up.
- Put set screw assembly on shaft, and align with the bolt holes of the laminates.
- Bolt laminates and screw screw assembly together.
- Tighten set screw to lock the laminate core to the shaft.
- Cut off any extra pieces of the bolts.

Step 6. Attach the magnets with epoxy. Let dry for at least 24 hours.

Step 7. Assemble the generator by inserting the new core (rotor) into the stator.

Costs

The generator core is inexpensive to build. Currently we only have cost estimates for components purchased in the US. A similar analysis needs to be done for Guatemala. This total only reflects the total material cost of the picoHydro generator-- the turbine, penstock, and other necessary equipment/labor costs would have to be added to this to

get the full cost of the system.

Item	Amount	Total Cost
Toyota Pick-up Alternator	1	$50
Magnets	12	$80
Shaft	1	$5
Bolts	2	<$1
Set Screw Assembly	1	<$1
Sheet Metal Laminates	40	$5
Epoxy	1 tube	<$1
TOTAL		**~$140**

In general we expect these time saving tools to save around $50 in labor costs, decreasing the overall cost of the system to make it affordable to people living in rural Guatemala.

Discussion

Our tools decrease the time required to convert an alternator into a generator from 3 days to 1 day. However, these tools are still in prototype phase.

There are other possible designs for cutting tool. Instead of using the aluminum angle ruler to align the shape you could drill holes into the base of the cutting tool that align with the holes of the laminate. A rods inserted into the aligned holes could be used to keep the laminate still during cutting.

There are some advantages and disadvantages with the proposed design:

- Advantages
  - If the holes are accurate it is possible to cut the laminate faster
  - In the current design the ruler is not attached on the base, and so it sometimes slips from the user's hand
  - The process will get faster
  - The tool can be less expensive, because it will utilize less material

- Disadvantages
  - Loss of accuracy with the wear of the material around the hole
  - Increases the complexity of manufacturing the tool, because it will require a great precision to make the holes

In addition to changes to the cutting tool several changes have been proposed to the drilling jig to make it easier to use.

Also, the original alternator rotor contained a series of blades which acted as a fan to cool the device when spinning. Our new permanent magnet rotor does not contain a fan and therefore excess heat may build up. It may be beneficial to incorporate blades into the new rotor design. However, we suspect that the generator will not get as hot as the

alternator did.

Next Steps

We are handing our findings, engineering drawings, and prototype tools off to AIDG so that they can continue the project in Guatemala.

These tools should be tested in the field in order so that their advantages and disadvantages can be determined and they can be redesigned as necessary. It is important to iterate through various designs after user testing.

In addition, it is necessary to:

- Determine how long the core manufacturing process takes, utilizing each proposed design, to see which one saves the most time
- Measure the efficiency of generator, and to propose some improvements to the design to extract the most amount of power
- Determine costs of materials and manufacturing in Guatemala to determine if the price point is reasonable

Conclusions

We succeeded in building three tools which allow a person to convert an alternator into a generator suitable for a 400W picohydro system more easily. Using our tools cuts the

time required to do the conversion from 3 days to less than 1 day. This will cut the price of the system significantly, making it more affordable to rural villages who need electricity.

What Did We Learn

The hardest part of this project was to get to the crux of the problem. We wanted to work on something useful, not only build a picohydro turbine or a generator. We began by considering the system broadly and did, in fact, develop a turbine from a bicycle wheel. However, we learned from AIDG that the main problem with their existing picohydro system was the speed of conversion of a pickup alternator into a generator, and so we decided to shift the focus of our project to improving the generator manufacturing process. Ultimately, we wanted to create an innovation that helps with the dissemination of this technology in rural communities, and therefore we had to make some very tough choices to continue or discontinue initial work on various aspects of our project.

Also importantly, we learned to work with people different cultures, different languages, and different ways of thinking. We had to be patient with those who have not mastered English, and so we found out other ways to communicate each other, such as drawing.

Contact details

Team members: Francesca Campagnoli (Italy), Johana Mathieu (USA), Rafael Barros Carrilho (Brazil), Gustavo Eidji Camarinha Fujiwara (Brazil), Shaibu Laizer (Tanzania), and Silvia Gonzalez (Ecuador).

Our mentors include Zubaida Bai, Gywn Jones, Kurt Kornbluth, Harald Quintus-Bosz, and Amy Smith.

To contact us please email the-hydropowers@mit.edu.

IDDS 2008 Pico Hydro Team - From left to right: Johanna, Francesca, Shaibu, Rafael, Amy, Sylvia, Gustavo.

External links

Picohydro

http://www.flickr.com/photos/29923614@N07/ Our Flickr account with some pictures of our project from IDDS 2008.

http://www.aprotec.com.co/pages/hidrica_pico.html In this Colombian webpage there is information about picohydro systems. (in Spanish)

http://www.eee.nottingham.ac.uk/picohydro/ Picohydro manuals, information, cases, etc.

http://en.wikipedia.org/wiki/Pico_hydro Picohydro definition and scales of hydro powers plants.

http://www.handsontv.info/series3/fuel_for_thought_reports/streamline_kenya.html Picohydro in real world: Kenya's case

Microhydro

http://microhydropower.net Information about microhydro power (with manuals).

http://www.microhydropower.net/basics/turbines.php#Crossflow Types of turbines.

Generator Components

http://www.kjmagnetics.com/ Super strong magnets.

Honduras

http://www.ahpper.org/2008/descargas.html The Honduran Association of Energy Producers webpage. On this page you can find useful information about the energy sector in Honduras. (in Spanish)

http://en.wikipedia.org/wiki/Electricity_sector_in_Honduras Wikipedia page for the Electricity Sector in Honduras.

http://ieeexplore.ieee.org/iel5/6998/18862/00870924.pdf?arnumber=870924 IEEE Xplore article about Honduras water power potential

http://www.esmap.org/filez/pubs/09506EnergyUsePrasadforWeb.pdf Honduras energy sector reform compared with Botswana, Ghana and Senegal

http://www.fao.org/nr/water/aquastat/water_res/honduras_wr.xls FAO webpage about Honduras water resources

Guatemala

http://www.usaid.gov/pubs/bj2001/lac/gt/ USAID website for Guatemala

http://www.aidg.org/ AIDG website, organization who helps individuals and communities get affordable and environmentally sound access to electricity, sanitation and clean water.

http://www.fao.org/newsroom/en/news/2004/49012/index.html FAO website for Guatemala

http://www.reeep.org/index.php?assetType=news&assetId=43 Sustainable energy for Guatemala, REEEP

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