PUNE RESEARCH DISCOVERY ISSN 2455-9202
AN INTERNATIONAL JOURNAL OF ADVANCED STUDIES VOL 8, ISSUE 2

GENERATION OF ELECTRICITY USING RAINWATER

SOURAV BABAJI LANKE[1]
PRASHANT TANAJI LONDHE[1]
YASH GORAKSHA DHAMALE[1]
ADARSH SANJAY PALWE[1]
Student
DIPALI BAGUL[1]
Project Guide

[1] Department of Civil Engineering
JSPM's Rajarshi Shahu Collage of
Engineering Polytechnic, Tathawade Pune
Maharashtra State Board of Technical
Education, Mumbai

ABSTRACT

The purpose of this project was to provide electricity that was sufficient for powering lights and charging cell phones in rainy locations with limited electricity access. A household rainwater energy harvesting system was researched, designed, prototyped, and tested to determine the feasibility of rainwater as a source of renewable energy. The system prototyped consisted of a gutter assembly that collected and funneled water from the roof to a downspout. The downspout shielded the stream of water from wind and directed it to a turbine at the ground level. The turbine was connected through a gear train to a DC motor serving as the generator. The device is optimal duringhigh rainfall intensities that produce larger flow rates. An Overshot water wheel, Crossflow turbine, and Pelton wheel turbine were evaluated under 8, 6, 4, and 2 gallons per minute flow rates using a tachometer and a torque meter. These flows were based on Liberian rainfall intensities scaled to a representative house that was 5 by 3 meters in roof area. The most suitable turbine was a 20 centimeter diameter Pelton wheel with 23 equally spaced blades. A micro gear motor rated at a maximum speed of 460 RPM and a stall torque of 20 ounce-inch was selected to serve as the generator. The system produced a power of 0.74 Watts and a 14.8% efficiency at 8 GPM. When scaled for the rainfall in the month of June, the current system could charge about 1.8 cell phones.

This project proved the concept and design of a rainwater energy harvesting system.

The system could be combined with a filtration system and holding tank to collect drinkable water so that the system serves a dual purpose for people with limited access to electricity and water.

INTRODUCTION

The global energy consumption was 575 quads in 2015, and is expected to increase by 28% by the year 2040 ("International Energy Outlook", 2017). Renewable energy is becoming the fastest growing energy type as countries switch from fossils fuels to various renewable sources. The benefits of obtaining energy from sources such as the sun, wind, and water are trifold. Renewable energy is helping tackle climate change, energy security, and energy access.

A global transition to renewable energy not only would combat climate change, but also has the potential to close the gap between those with and without electricity. There is a connection between access to electricity and the ability for economic and human development to occur, termed energy poverty (González-Eguino, 2015). In today's world, over 1.4 billion people face energy poverty. The challenge of energy poverty is concentrated in rural areas, where 85% of the population lacks electricity access (Stram, 2016). Rural renewable electrification programs are an opportunity to help combat energy poverty.

Our Major Qualifying Project will work to target rural electrification and clean water access in areas with high levels of rainfall through a rainwater collection and pico-hydropower harvesting device. Accessing water is an energy intensive process and recognizing the intersection between energy and water and using rainwater harvesting to approach the problem is a research area being pursued (Vieira, Beal, Ghisi & Stewart, 2014). The goal of our project is to create a pico-hydropower energy collection device that can be implemented into a rainwater harvesting system in order to provide electricity when solar energy is not available. Our project will target the needs of rural Liberia, where 70% of the population lives in multidimensional poverty, and of the rural population only 1.2% of people have access to electricity and 56% have access to improved drinking water (United Nations Development Programme, 2016; Liberia Institute of Statistics and Geo-Information Services, 2013). More than 40% of the people living in rural Liberia have access to a cell phone or a radio and almost all of the rural population has some method for accessing lighting; (Liberia Institute of Statistics and Geo- Information Services, 2013). The development of technologytailored to the social and cultural needs of specific rural areas is critical to their success (Urmee & Md, 2016). In our project we will not delve deep into the social side of the pico-hydropower energy and rainwater harvesting system, however we have assessed the rural electricity uses and strategies for accessing water. Our project will work to target the scarcity in rural electricity and water through the development of a rainwater energy harvesting system.

3.1 MAIN BODY

The gutter and downspout sub-system includes the gutter, the gutter-to-downspout connector, and the downspout itself. This section outlines the calculations, considerations, and teststo determine the gutter sizing and slope, the preferred gutter-to-downspout connection, and the downspout design to develop a final design for the sub-system.

Gutter Sizing and Slope

Sizing the gutter to contain the water coming off the roof was the first step of designing this sub-system. The gutter sizing calculations were completed using two approaches. The first approach determines the velocity and projection of the water coming off the roof to determine the necessary width of the gutter.

Gutter-to-Downspout Connection Types

There are several different ways to connect a gutter to a downspout. The most common type of connection involves a funnel-like component on the gutter that connects to the downspout. Most of the time elbow connectors and short lengths of downspouts are attached to the funnel connection to lead the downspout back to the side of the house to be supported, However, the downspout may not require the elbow connections if it can be supported by a structure other than the side of the house, Another option we came across was simply an

open end of a gutter that emptied into a vessel for collecting the rainwater,

Elbow Connectors and Short Lengths of Downspout

(Photo Credit: USA Gutters, 2018)

Straight Downspout *Photo Credit: DZ/DG, 2018)*

Figure : Open End Gutter

(Photo Credit: Eggleston Farkas Architects)

Gutter-to-Downspout Connection Tests

To determine the most suitable gutter-to-downspout connection, we conducted preliminary testing of five different types of connections: vertical downspout (Figure 22), bent downspout (Figure 23), vertical downspout with 1.4 centimeter and 1.1 centimeter funnels placed at the top of the downspout (Figure 24), and the open end gutter. The connection ideally should produce a single stream, or at least a primary stream, of water to strike the turbine. If the water disperses too much, the stream would not be powerful enough to start the turbine. The hose was placed in the gutter and each connection was evaluated at four different flow rates: 8 GPM, 6 GPM, 4 GPM, and 2 GPM. After initial tests, the open end gutter was immediately eliminated because the position of the stream changed drastically for each flow rate. This would not be feasible for the system as the turbine would have to be moved frequently to adjust to the position of the stream.

CONCLUSIONS

The goal of this project was to provide energy from rainwater to charge cell phones or batteries for light in areas that had a lot of rainfall but minimal electricity. We identified Liberia as a case study area for our implementation due to it having a yearly rainfall rate of over 2500 millimeters(98.4 inches) a year (Golder Associates, 2012) and less than 1.2% electrification rate in rural areas (Liberia Institute of Statistics and Geo-Information Services, 2013). Using estimates for Liberian rainfall rates, our system could produce 2,664 Joules of energy in only a 30-minute rainstorm with a flow of 8 gallons per minute. This is enough to charge a cellphone approximately 13%. A monthly approximation for the number of cell phones can be made based on the system efficiency of 15%, a roof of 5 meters by 3 meters, a height of 3 meters, and using data for the average rainfall in the rainiest month, which is June and 533 millimeters (21.9 inches) of rain (Golder Associates, 2012).

REFERENCES

American Building Components - Metal Roofing & Wall Panel Colors. (n.d.). Retrieved March 21, 2018, from http://abcmetalroofing.chameleonpower.com/

Bhargav, M. M. S. R. S., Ratna Kishore, V., Anbuudayasankar, S. P., & Balaji, K. (2016). Power generation by high head water in a building using micro hydro turbine—a greener approach. Environmental Science and Pollution Research, 23(10), 9381–9390. https://doi.org/10.1007/s11356-015-5317-6

Cobb, B. R., & Sharp, K. V. (2013). Impulse (Turgo and Pelton) turbine performance characteristics and their impact on pico-hydro installations. Renewable Energy, 50, 959–964. https://doi.org/10.1016/j.renene.2012.08.010

"Comparison between Impulse Turbine and Reaction Turbine" (2016). Retrieved October 14, 2017, from https://me-mechanicalengineering.com/comparison-between-impulse-turbine-and-reactionturbine/

Gkavanasios, J. (2017, September 18). Pelton Turbine[SolidWorks Part]. GrabCad.

Golder Associates. (2012). Liberty, N. E. W., Mine, G., Environmental, P., & Statement, I. Section B: Surface Water Assessment Report.

González-Eguino, M. (2015). Energy poverty: An overview. Renewable and Sustainable Energy Reviews, 47, 377–385. https://doi.org/10.1016/j.rser.2015.03.013

Green Energy. (n.d.). Retrieved March 21, 2018, from http://www.partnerliberia.org

International Energy Outlook, IEO2017 (September 14, 2017).

Kanth, B. P., Ashwani., & Sharma, S. (2012). House Hold Power Generation Using Rain Water. The International Journal of Engineering, 1(2), 77–80. Retrieved from www.theijes.com

Liberia Institute of Statistics and Geo-Information Services. (2013). Liberia Demographic and Health Survey 2013, 480. Retrieved from http://dhsprogram.com/publications/publication- fr291-dhsfinal-reports.cfm

Munson, B., Okiishi, T., Huebsch, W., Rothmayer, A. (2013). Fundamentals of Fluid Mechanics.

Hoboken, NJ: John Wiley & Sons.

Okot, D. K. (2013). Review of small hydropower technology. Renewable and Sustainable Energy Reviews, 26, 515-520. https://doi.org/10.1016/j.rser.2013.05.006

Quaranta, E., & Revelli, R. (2015). Output power and power losses estimation for an overshot water wheel. Renewable Energy,83, 979-987. doi:10.1016/j.renene.2015.05.018

SHAH, Q. (2014, October 8). CrossFlow turbine[SolidWorks Part]. GrabCad.

SMACNA. (2012). Architectural Sheet Metal Manual: Technical Publication. Chantilly, VA: Author.

Still, G., & Thomas, T. (2002, December). THE OPTIMUM SIZING OF GUTTERS FOR DOMESTIC ROOFWATER HARVESTING(Rep.). Retrieved March 21, 2018, from University of Warwick website: https://warwick.ac.uk/fac/sci/eng/research/grouplist/structural/dtu/pubs/wp/wp56/wp5 6.pdf

Stram, B. N. (2016). Key challenges to expanding renewable energy. Energy Policy, 96, 728–734. https://doi.org/10.1016/j.enpol.2016.05.034

Tester, J., Drake, E., Driscoll, M., Golay, M., & Peters, W. (2016). Sustainable Energy: Choosing Among Options (2nd ed.). Cambridge, MA: The MIT Press.

Understanding D.C. Motor Characteristics. (n.d.). Retrieved March 21, 2018, from http://lancet.mit.edu/motors/motors3.html

United Nations Development Programme. (2016). Human Development Report 2016. United Nations Development Programme. https://doi.org/eISBN: 978-92-1-060036-1

Urmee, T., & Md, A. (2016). Social, cultural and political dimensions of off-grid renewable energy programs in developing countries, 93, 159–167. https://doi.org/10.1016/j.renene.2016.02.040

V. (2015, April 10). Waterwheel [SolidWorks Part]. GrabCad.

Vieira, A. S., Beal, C. D., Ghisi, E., & Stewart, R. A. (2014). Energy intensity of rainwater harvesting systems: A review. Renewable and Sustainable Energy Reviews, 34, 225–242. https://doi.org/10.1016/j.rser.2014.03.012

Waterwheel Design and the Different Types of Waterwheel. (2013). Retrieved October 14, 2017, from http://www.alternative-energy-tutorials.com/hydro-energy/waterwheel-design.html

World Energy Council. (2016). World Energy Resources 2016. 1-1028. Retrieved from https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Resources- Full-report-2016.10.03.pdf.

WIN, Z., WIN, H., & THEIN, M. (2016). DESIGN, CONSTRUCTION AND PERFORMANCE

TEST OF CROSS-FLOW TURBINE. International Journal of Mechanical And Production Engineering,,4(12), 95-100.

Williamson, S. J., Stark, B. H., & Booker, J. D. (2014). Low head pico hydro turbine selection using a multicriteria analysis. Renewable Energy, 61, 43–50. https://doi.org/10.1016/j.renene.2012.06.020

Wu, W., Geng, P., Li, G., Zhau, D., Zhang, H., & Zhao, J. (2015). Influence of

Layer Thickness andRaster Angle on the Mechnical Properties of 3D-Printed PEEK and a Comparative Mechanical Study between PEEK and ABS. Materials, 8(9), 5834-5846.

Doi:10.3390/ma8095271

Zhou, D., & Deng, Z. (Daniel). (2017). Ultra-low-head hydroelectric technology: A review.

Renewable and Sustainable Energy Reviews, 78(March 2016), 23–30. https://doi.org/10.1016/j.rser.2017.04.086

Židonis, A., & Aggidis, G. A. (2016). Pelton turbine: Identifying the optimum number of buckets using CFD. Journal of Hydrodynamics, Ser. B,28(1), 75-83. doi:10.1016/s1001-6058(16)6