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Cost-efficient and simple hands-on experiments for education in renewable energy systems

Anurag Mohapatra[1], Johannes Krell[2], Stephan Baur[3]

Motivation

Renewable energy (RE) practical lessons in school are mostly restricted to demonstration sessions run by an instructor handling expensive equipment or limited field trips where students observe the plants at a distance. The unidirectional lecturing and lack of hands-on exposure further alienates the student and makes renewable technology seem mysterious. The authors propose a hands-on education framework suitable for high school and university students which explains a vast majority of RE concepts through simple experiments using low-cost equipment for classrooms of up to 30 students which encourages Active Learning and Practice Oriented Teaching.

Implementation

1 Week “block course” format breakdown

Day 1

- Energy and electricity basics with mechanical analogy; Solar energy basics
- Demonstration of PV panel under different operating conditions

Day 2

- Measurement of power usage by daily appliances
- Demonstrate effect of orientation with sun on PV panel output
- Concept of electical grid with mechanical analogy

Day 3

- Measurement of PV parameters under different opearting conditions
- Alternating current and power conversion mechanisms
- Demonstrate working principle of a battery inverter

Day 4

- Spreadsheet analysis of data from experiment on Day 3
- Series and parallel connections for batteries and PV

Day 5

- Capacity factor of PV and sizing of an energy system
- Demand based renewable energy system sizing
- Battery technologies with mechanical analogy of charge transfer

Day 6

- Measurement with battery connections over load
- Wind energy basics and factors affecting wind turbine output
- Demonstration of wind turbine under different operating conditions

Day 7

- Measurement of V & I for wind turbine in different operating conditions
- Design a solar PV system with storage for the specific requirements of the school

- Theoretical explanation
- Demonstration by tutor
- Experiment by students
- Data analysis on computers
- Real world scenario project

Required equipment and tools

- Multimeter
- 20W Solar PV panel
- Small Rheostat for Rload
- DC motor 9V
- Batteries 9V and AAA
- Toy drone blades
- Reusable plug play circuitboard
- Various coloured LEDs
- Various resistors
- Connecting wires
- Electrical tape
- Old hair dryer or table fan with variable speed
- Spreadsheet software on PC (RPi or Linux possible)

Assessment

The course was conducted in the above mentioned format in St. Rupert Mayer High School, Makonde, Mashonaland West, Zimbabwe with 22 students aged 14 – 18 The students had minimal previous exposure to the subject matter due to lack of a science lab. At the end of the course, every attendee was able to independently define and design a solar PV system with battery backup for the specific demands of their own school.

Next steps

A course kit to be developed with the necessary equipment, instructional video manuals and detailed lesson plan for block course and regular school curriculum inclusion. Course to be expanded to include biogas, hydro power and solar thermal. Microcontroller based sensors to be added for the university level coursework.

Chair of Renewable and Sustainable Energy Systems,
Lichtengbergstr 4a, Garching b. Munich, 85748
Email: anurag.mohapatra@tum.de
Web: www.ens.ei.tum.de

[1]Masters in Power Engineering
Department of Electrical and Computer Engineering
Technical University of Munich

[2]TUM School of Education
Chair of Education Science
Technical University of Munich

[3]Department of Electrical and Computer Engineering
Chair of Renewable and Sustainable Energy Systems
Technical University of Munich