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Design & Construction of a Low-Cost Meteorological Station

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Motivation & Background

Approximately 1.1 billion people worldwide are still living without electricity [1], most of them in rural areas of sub-Saharan Africa and the Asia-Pacific. In addition to the already existing deficits regarding access to electricity in these areas, a strong increase in demand for electricity is predicted for the future.

Renewable energy systems offer many opportunities for developing countries. The use of renewable off-grid technology, such as mini-grids and individual solar home systems, offers varying possibilities for improvement of the living conditions in developing countries.

Since the construction of isolated systems is quite complex and costly, it is essential that the construction and placement of renewable energy systems is correct from the start. This requires long-term information, which can be analyzed for the local energy potential as well as for extreme weather conditions.

Existing meteorological stations are very expensive and are often not suitable for the use in remote and rural areas. This project aims to develop a low-cost meteorological station especially designed for the use in these areas.

Concept for the Meteorological Station

The station's design is based on a Raspberry Pi single-board computer (Fig. 1). The developed station provides reliable measurements for long-term acquisition of meteorological information, including wind speed, temperature, rainfall and solar radiation. Three prototypes were site tested in Zimbabwe and one station in Nepal (Fig. 2). The findings were implemented as hardware and software updates in the current version. The total material cost of a station amounts to about 320 U.S. Dollars.

Solar Radiation Measurement

To measure solar irradiation, i.e. insolation, typically a pyranometer is used. As a pyranometer is too expensive for the project, an attractive alternative was found:

- Mini solar cell (300 mA / 1.5 V)
- Correlation between radiation and short-circuit current
- Approaching the short-circuit current by measuring the voltage drop at a 0.75 Ω resistor
- Coherency between the curves of the mini solar cell and the pyranometer (Fig. 4)

Temperature Measurement

To measure temperature, a cheap and standard temperature sensor is used:

- Digital thermometer DS18B20 from Maxim Integrated
- Waterproof
- 12-bit temperature measurement
- Raspberry Pi reads out the bit strings

Autarkic System

As in rural areas regular power supply cannot be taken for granted, the meteorological station is equipped with a self-sufficient power supply system:

- 20 W solar panel and charge controller
- Two 7.2 Ah batteries

Fig. 1: Raspberry Pi [2]

Raspberry Pi

Data Transmission

Normally, it is time intensive and expensive to reach the stations placed in remote areas. Therefor, a basis for data transmission has been established:

- Internet connection via mobile network using a wireless USB modem
- Upload data to a central FTP server
- Self-built FTP-Server by setting up PiNAS

Wind Measurement

To measure wind velocity, a standard wind sensor is integrated:

- Wind Sensor WS from Eltako Electronics
- Reed switch and two magnets
- Electric impulse detected directly by Raspberry Pi
- Sensor calibration in wind tunnel
- Impulses per second n $[s^{-1}]$ are depending linearly to the wind velocity v $[ms^{-1}]$

Rainfall Measurement

To measure the rainfall a rain sensor was specially designed and built:

- 3D-printed rain sensor
- Tipping bucket rain gauge
- Tipping bucket tilts over at a certain volume of rainfall
- Reed switch and magnet create impulses
- Electric impulse detected by Raspberry Pi
- Conversion of the impulses to volume of rainfall during a time interval

Fig. 2: Site test in Zimbabwe

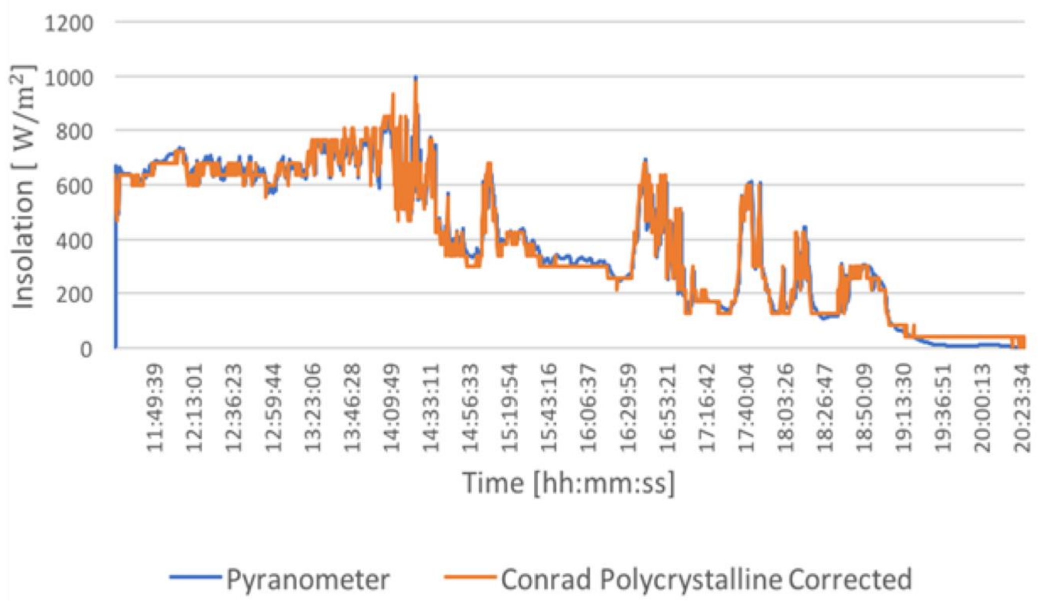

Fig. 3: Comparison: Pyranometer and Small Solar Cell

Fig. 4: First Prototype of the station

Outlook

The project's vision is to create a manual for the construction of the station (Fig. 4) and to make it publicly available, for example on an internet website. The low material costs as well as the possibility for local manufacturing based on the open source idea increases the project's sustainability. This allows the construction of the station and the establishment of a global network to determine renewable energy potential and identify optimal sites for renewable energy systems. Also, this project represents an interesting university project, as it confronts students with versatile and interesting challenges and combines different hardware and software aspects.

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References

[1] International Energy Agency (2017) *WEO-2017 Special Report: World Energy Access Outlook*. Paris: IEA Publications.

[2] Raspberry Pi Foundation (2017). *Raspberry Pi*. Web page. Retrieved on 17.01.2018, from www.raspberrypi.org/products