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MEASUREMENT METHOD FOR A SOLAR CELL INDUCED GRAVITY VENTILATION SYSTEM

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Abstract

A zero-energy research program was recently established. Under this research program, we collaborated with another department. The goal of the collaboration was to develop a gravitational, zero-energy ventilation system sufficiently efficient to use in a passive house or in a zero-energy building. We developed a method to measure all of the necessary variables and parameters required to calculate the effectiveness of the theoretical description of the approach.

Key words: battery management, photovoltaic panel, zero energy building

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1. Introduction

A new Zero Energy research program was recently established. The goal of the research program was to perform measurements to fortify a theory of another department. Our aim was to construct an experimental room with only one ventilation channel (Chen et al., 2010). This ventilation must occur without any additional energy consumption. In the volume of the room, we must measure the temperature of the room, the outside environment and the ventilation channel, which was covered with a photovoltaic panel, as well as the airflow inside the ventilation channel.

2. Experimental methods

The first step was to establish the experimental circumstances. We built a room that is isolated from the environment. The size of the room was 2.5 m × 7.5 m. On the southeastern wall of this experimental room, we made a ventilation channel, (net area of 52 cm^2) covered by a tilted photovoltaic (PV) panel. Inside the room and both outside and in the channel, we placed digitally readable thermometers, type LM35 precision centigrade temperature sensors (Texas Instrument, 2013). The airflow sensor was a hot-wire anemometer in a homemade bridge topology because of the special size and the low airflow values. The core unit of this sensor-amplifier is an INA126 instrumentation amplifier. Application information and a sample circuit schematic are in the datasheet for the bridge type sensors used.

To obtain the produced electrical energy from the PV panel, we produced a circuit to as a load of the panel. The load circuit was a battery charging and discharging system. We measured the produced electrical energy by measuring the load current and the voltage in the terminals of the PV.

There was also a thermometer in connection with the PV panel to determine the thermal efficiency of our PV panel (Caluianu and Baltaretu, 2012). The schematic setup is shown in Fig. 1a, and a real-life image of the setup is shown in Fig. 1b.

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Long-term measurements were performed using a computer data acquisition system. The analog-digital converter unit was three pieces of the NI-myDAQ data acquisition module (National Instruments, 2011). Only two analog inputs are provided in the unit, but the main advantage of using such a unit is the NI graphical program language, known as LabView. This programming environment contains many pre-defined function blocks (called VI-s). The programming of LabView performed by connecting these function blocks to each other in a notably user-friendly tool, instead of programming complicated low level codes. Fig. 2a shows the programming environment, particularly the airflow data collecting module of the program. Fig. 2b shows a sketch of the setup of the data acquisition system.

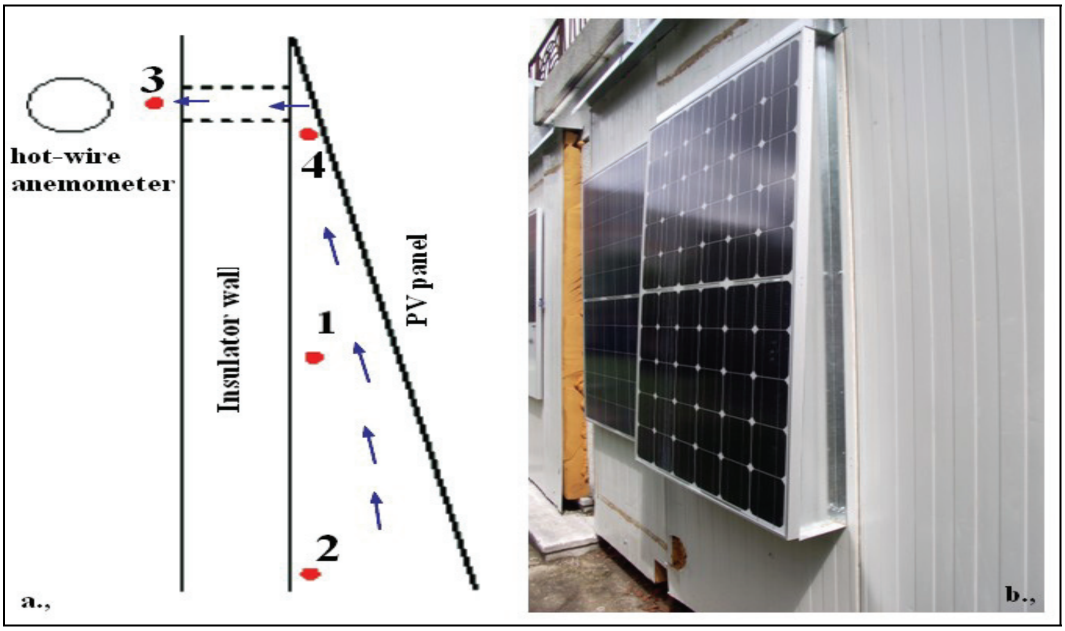

Fig. 1. a - the schematic arrangement of the sensors and PV panel; b - image of the PV panel mounted on the ventilation channel

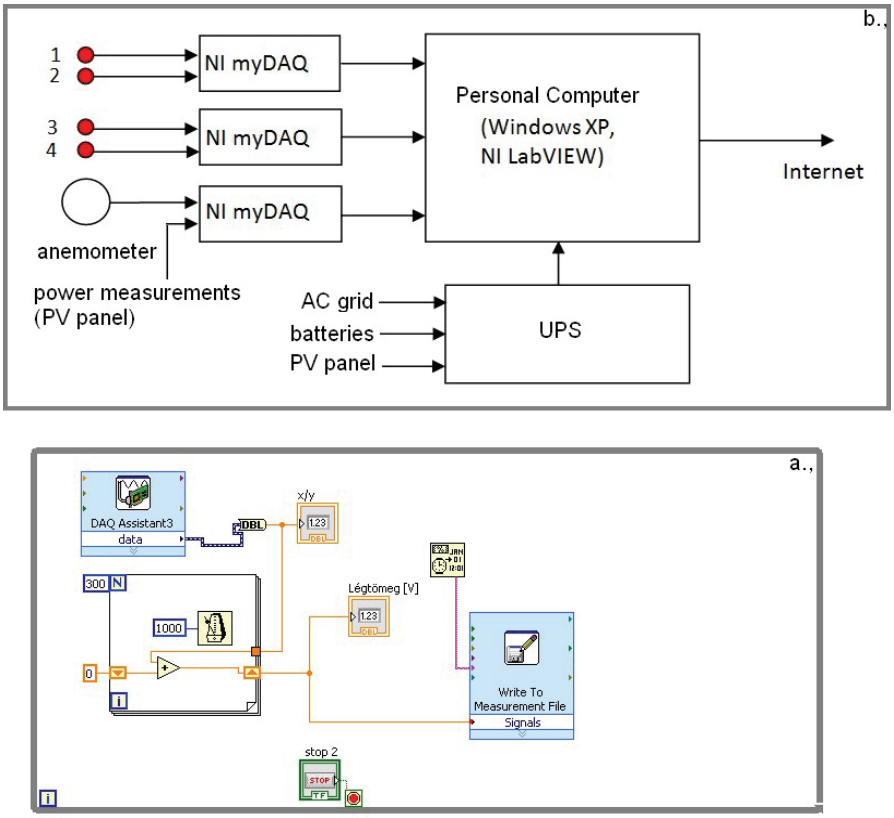

Fig. 2. a. - data acquisition VI of the anemometer; b - schematic of the data acquisition system

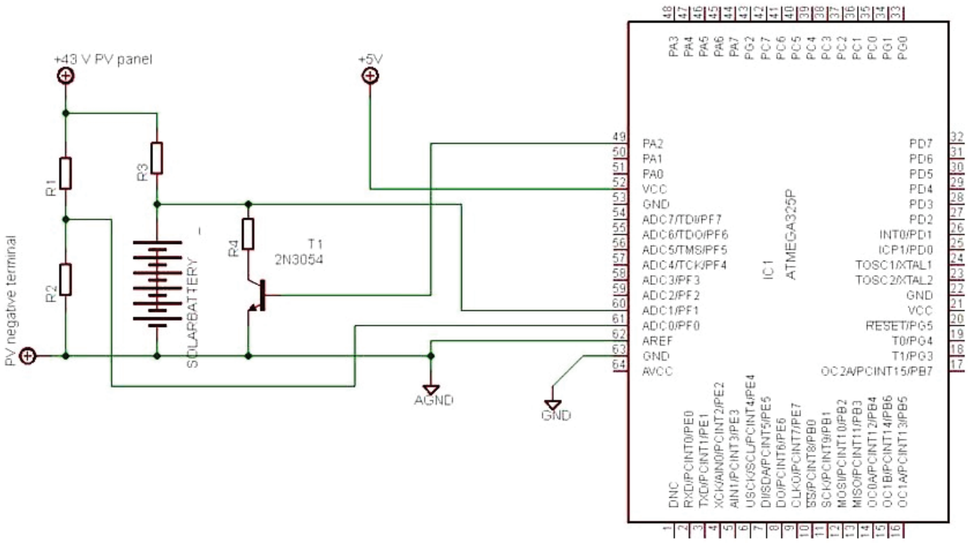

Fig. 3. Planned PV power measure circuit

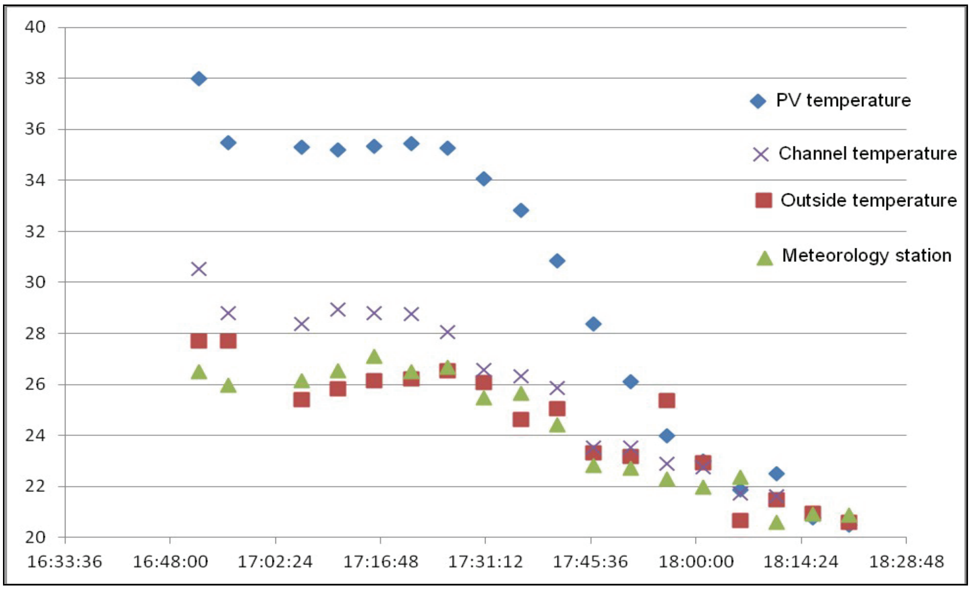

Fig. 4. Temperature sensor check

Power data from the PV panel was calculated by collecting the irradiance information during measurement. The hardware was a MacSolar SLM-018c-2 solar measuring device (Solarc, 2011). With the collection of irradiance and temperature information, a MacView program can calculate (if the type of the PV panel known) the actual power of the PV at a given time.

There are four different units used for the measurement. It is essential to record a time stamp for every unit for later evaluation. The MacSolar unit has a built in data storage system, containing the time stamp as well. In the NI LabView program, we also recorded the time stamp of a given measurement. Every value coming from the sensors were collected and averaged to a 5-min period of time. Subsequently, we observed that for the calculations, only one-hour averages are necessary.

After collecting a 5-min average, the acquisition system connects to a cloud server to store the data in a place, where all of the researchers involved in the research project can access it. Subsequently, we plan to build such a system that we can use in education. Data management and result presentation is difficult to teach without any real world data.

To verify the correctness of our solar power gain calculations, we plan to making direct power measurements on the PV. The schematic of measurement device can be found in Fig. 3.

3. Results and discussion

We started data collection with the above mentioned setup in the beginning of 2014. At first glance, it is clear that there is some other source of ventilation in our experimental room. After recognition of this systematic error, we added more insulation in the room to eliminate this excess. We also performed some error correction during the calculation.

It was not necessary to calibrate the LM 35 centigrade temperature sensor because it was made during the production process, as the datasheet says, and the output of the sensor is thermal compensated for precise measurement. A temperature plot during the test measurement can be seen in Fig. 4. We have checked the good placement of the sensors and the values using an independent meteorology station.

The home-made anemometer must be calibrated. The anemometer was made with a high precision, industrial grade anemometer type Testo 425 (Testo, 2012). A sample of the data of the collected values in a given day is presented in Table 1. Significant airflow can occur when the solar panel is warm enough to increase the temperature of the ventilation channel. However, during night hours, especially when sunrise is close, significant airflow was also observed. This phenomenon is due to the heat transfer through the wall of the room, especially during winter days.

The airflow in daylight hours of the previous table was plotted versus the outside temperature, as shown in Fig. 5. From our group's perspective, the dependence of the produced energy of the PV panel on the channel temperature is important. In theory, the PV efficiency decreases when the temperature of the PV panel increases (Celik et al., 2009). Therefore, the cooling effect of this ventilation channel could be significant, especially during hotter summer days (Brinkworth and Sandberg, 2006).

Because of the timetable of the project, no opportunity was available to check these phenomena in practice; as a result, the next step of our research is to build the abovementioned energy measuring device for PV panels and to verify the above-mentioned dependency. With the current system, we can now compare a relatively sunny day (when the irradiance is high) when the average outside temperature is not higher than 10 °C to a day with a similar irradiance, but the outside temperature is higher. Such a comparison is shown in Fig. 6.

More experiments are being performed on the topic of the output energy dependence of the PV module of various types of solar panels (amorphous, mono-crystalline, and poly-crystalline). Because of the different crystalline structure, this thermal dependency could be different for the different solar cell types.

We checked the dependencies of the individual parameters among each other. We produced a normalized and compensated value chart, which contains the airflow, the generated power and the room temperature dependency from outside temperature in one chart, as shown in Fig. 7.

Table 1. Collected data averages 21. 02. 2014

Time stamp	$<T_{channel}>$ °C	$<T_{outside}>$ °C	$<T_{room}>$ °C	*<airflow>* m^3/h	$<T_{channel}>-<T_{outside}>$ °C	*PV panel energy (Wh)*
2014.02.24 0:56	1.19	2.04	5.60	4.02	0.85	0
2014.02.24 1:56	1.68	2.71	5.36	5.04	1.03	0
2014.02.24 2:56	2.18	2.50	5.81	3.82	0.32	0
2014.02.24 3:56	2.20	2.66	5.59	6.03	0.46	0
2014.02.24 4:56	2.44	3.81	5.80	4.17	1.37	0
2014.02.24 5:56	2.49	2.69	5.91	4.21	0.19	0
2014.02.24 6:56	2.10	2.79	5.48	5.39	0.69	0
2014.02.24 7:56	3.33	3.62	5.71	5.67	0.29	0.002411254
2014.02.24 8:56	5.74	4.88	5.99	5.63	0.86	0.765117982
2014.02.24 9:56	7.68	6.52	6.73	4.44	1.16	2.366994785
2014.02.24 10:56	12.64	9.90	9.10	5.41	2.74	4.683695811
2014.02.24 11:56	24.90	14.81	13.89	6.07	10.09	24.99660909
2014.02.24 12:56	22.89	15.63	13.96	6.20	7.26	23.86037382
2014.02.24 13:56	17.17	13.09	11.01	5.65	4.08	46.04280593
2014.02.24 14:56	11.93	11.26	9.26	4.57	0.68	18.95377466
2014.02.24 15:56	10.70	10.00	9.28	5.91	0.70	4.799463999
2014.02.24 16:56	8.04	8.66	7.89	5.73	0.62	5.461380323
2014.02.24 17:56	5.30	6.37	7.30	3.35	1.07	0.827038605
2014.02.24 18:56	3.93	5.01	7.47	2.51	1.08	6.52657E-05
2014.02.24 19:56	4.13	5.33	7.11	3.32	1.20	0
2014.02.24 20:56	3.60	5.11	7.12	2.64	1.51	0
2014.02.24 21:56	3.14	4.16	7.02	3.30	1.02	0
2014.02.24 22:56	3.28	4.31	7.12	2.91	1.03	0
2014.02.24 23:56	4.30	4.65	7.37	2.50	0.35	0

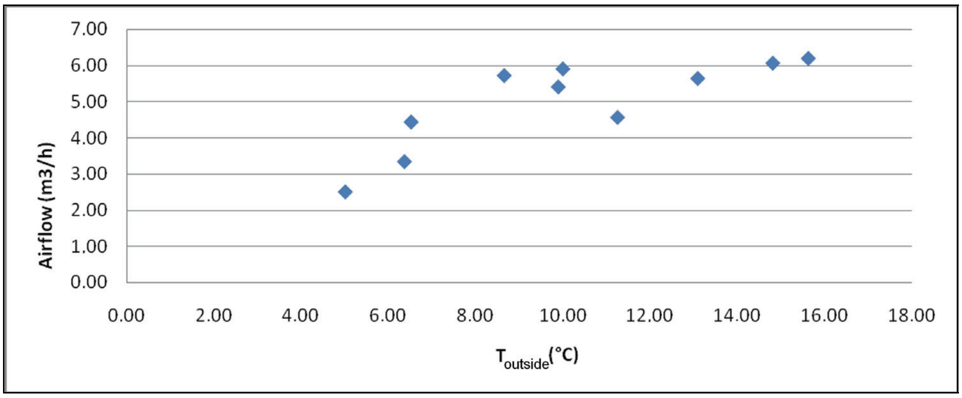

Fig. 5. Outside temperature dependence of the airflow

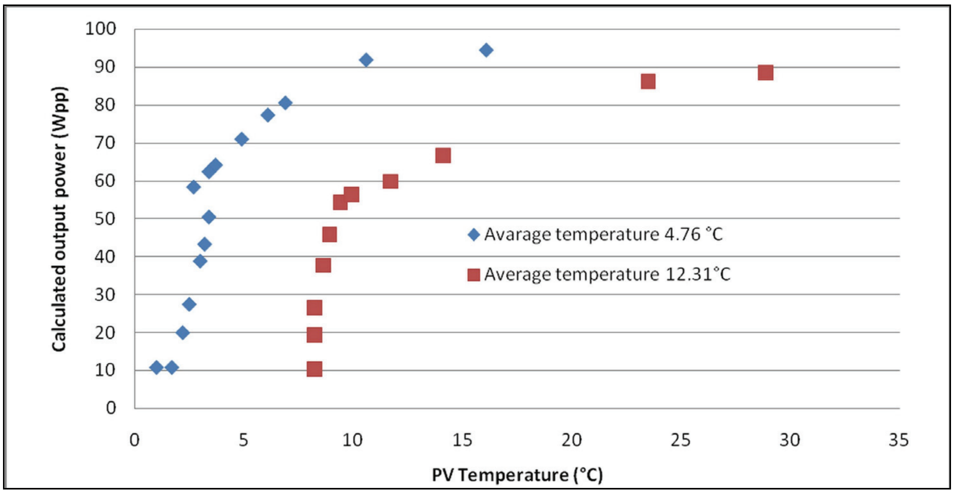

Fig. 6. The output power-peak dependence of the module temperature

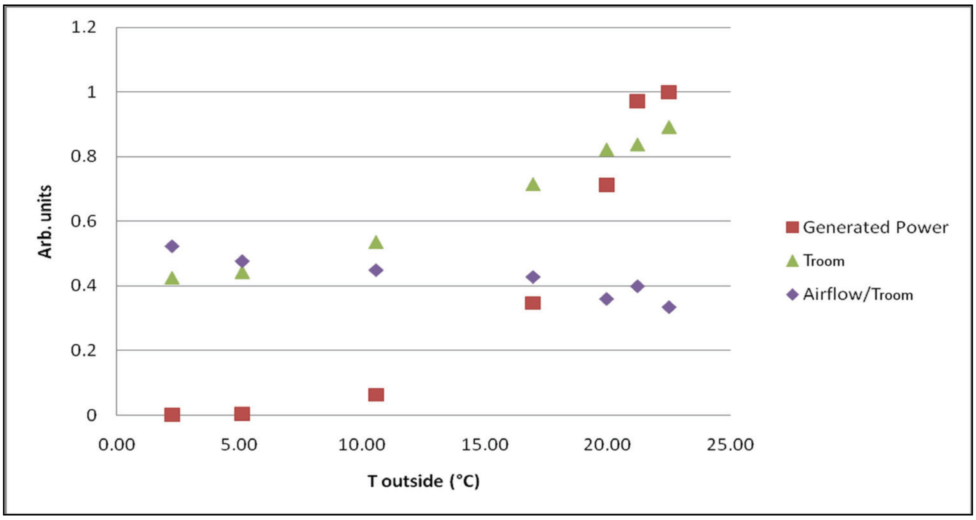

Fig. 7. Various dependencies during the measurements

4. Conclusions

Examining the literature, notably few articles discuss a similar ventilation structure to the above-described structure. We observed that it is possible to achieve smaller energy consumption in a zero energy building when we use such a ventilation system based on a PV panel.

Because of some special weather conditions and the timetable of the research, more data are required to define exactly how much excess energy can be possible using this gravitational ventilation using a PV panel. With the cloud technology of the internet, the data can directly be stored in such a way that larger communities of researchers, an educational institute can access it.

Acknowledgments

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