Detecting the presence of pigeons on PV modules in a pico-solar system

Pierre E Hertzog[1] and Arthur J Swart[2]

[1,2]*Department of Electrical, Electronics and Computer Engineering*

Central University of Technology, Private BagX20539, Bloemfontein, 9300

[1]phertzog@cut.ac.za

[2]aswart@cut.ac.za

Abstract—**Shading caused by the presence of pigeons can negatively affect the output power of a PV module in a pico-solar system. This is due to the fact that the body of the pigeon may interrupt the direct beam radiation received by a cell, or number of cells, resulting in output power loss and internal power dissipation within the PV module, as the shaded cells become reverse biased. Detecting the presence of pigeons and then deploying some type of intervention to scare the pigeons away may assist in reducing the shading time, thereby enabling the availability of maximum output power and reduced hot spots. The purpose of this paper is to present the design and results of a LabVIEW software system that was used to detect the presence of pigeons on PV modules in a pico-solar system. The developed system monitors the output voltage and current of multiple identical PV systems, and if a significant drop in current is detected in one system, while the others remain constant, then the system registers an event and logs the amount of time in 10-second intervals. For each sample of this event, the system records an image of the PV modules using a high definition webcam. Correlating the images to the actual events reveals an 86.4% accuracy, thereby indicating that the developed system is indeed detecting the presence of pigeons on the PV modules. It is further recommended to now integrate into this system some type of intervention which may be used to scare the pigeons away.**

***Keywords*— Arduino, LabVIEW, Webcam, shading,**

I. INTRODUCTION

The negative influence of the presence of birds in the vicinity of photovoltaic (PV) installations is covered in many research papers and articles [1-3]. One negative influence is that of shading caused by the presence of the bird itself or from the droppings left by the birds. The exact influence of birds on the performance of a PV system depends largely on its size and on the number of birds present. In this study, a system was developed that detects the presence of pigeons on a pico-solar system that is used for research purposes at the Central University of Technology (CUT) in South Africa. Because of the small size of these PV systems at CUT (less than 10 W peak), shading by pigeons poses a major problem, as small PV cells are involved.

The purpose of this paper is to present the design and results of a LabVIEW software system that was used to detect the presence of pigeons on PV modules in a pico-solar system. The developed system monitors the output voltage and current of multiple identical PV systems, detecting if there is a sudden drop in the amount of current drawn by a solar controller that is connected to the PV modules. An image is then recorded, by the LabVIEW software, of the PV modules and used to confirm the presence of the pigeons. In the next section, a short literature review on the influance of birds on PV systems, the LabVIEW software that was used and solar system sizes will be done. This will be followed by a section where the study context and research site is explained. The research methodology (including practical setup) follows along with the results, discussion and conclusion.

II. LITERATURE REVIEW

A. Birds

The presence of birds on PV modules can cause partial shading, which is primarily depended on the size of the bird, the number of bird-droppings, the presence of nests and the size of the PV installation. A significant negative impact on the performance of the system can result [4, 5], including lower output powers and the development of hot spots. Hot spots occur when several series connected cells are dissipating power in a shaded PV module. This results in the individual PV cells (or modules in the case of an array) being forced to operate at a different power level, other than their own, which leads to losses in overall output power [6]. These hot spots are a common problem in PV systems, accelerating cell degradation and reducing system performance [7], occurring mainly during the day when ambient temperatures are above the standard test condition (STC) level and the maximum power current is being drawn. This shading may be caused by the physical body of the bird (which now interrupts direct beam radiation) or by what the bird leaves behind, primarily being bird-droppings. This causes partial shading of PV modules and proves difficult to clean [2, 8].

Another problem caused by birds is nesting near or on the PV modules[9]. These nests may cause additional shading, and the continued presence of the birds close to the nests will cause regular shading to occur. The location of the PV installation site often dictates the tilt angle of the installation[10]. If this angle is relatively low, then it is assumed that pigeons would be more inclined to sit on the module. With a 29° tilt angle in Bloemfontein, the top edge of the PV modules form a very comfortable seating area for the pigeons.

B. LabVIEW

National Instruments LabVIEW is a graphical programming language that has its origins in automation. Its

978-1-5386-2774-7/17/$31.00 ©2017 IEEE

graphical illustration, similar to a process flow diagram, was created to provide an instinctive programming environment for scientists and engineers. The language has progressed over the last 20 years to become a general-purpose programming environment. LabVIEW has several key features which make it a good choice in automation [11]. These include simple network communication, powerful toolsets for process control and data fitting, fast and easy user interface construction, and an efficient code execution environment [12].

C. Solar system sizes

Advances in light emitting diode (LED) technology, including falling prices and efficacy improvements, have already sparked development of a rapidly growing market for "pico-solar" systems, that are PV systems with modules smaller than 10 W peak, for off-grid lighting and mobile phone charging [13]. These type of systems are ideally suited to balconies of residential flats or for portable use in remote places. A pico-solar system may consist of only one 10 W module.

Large numbers of micro-solar systems have also penetrated the market, being defined mainly as household systems which may or may not be connected to the grid [14]. These may include a number of PV modules connected together in an array with output powers typically less than 10 kW. A micro-solar system may consist of approximately 33 PV modules (each 300 W) that are connected in series and parallel.

Compared to well-studied macro-solar systems (these include electricity generation for residential and commercial buildings), the extraction of power from micro-solar systems is more constrained in the energy budget and use, and is still under active research [15]. These macro-solar systems typically produce output powers of less than 200 kW and may consist of up to 700 PV modules (each 300 W) connected in series and parallel.

III. Context of the Study

South Africa has good solar resources, where the average daily solar irradiation varies between 4.5 and 7 kWh / m^2 [16]. In the centre of South Africa lies the Free State province with Bloemfontein as the provincial capital. The main campus of CUT is in Bloemfontein where the Faculty of Engineering and Information Technology is located.

The co-ordinates of CUT's main campus is 29°07'17.24" S (Latitude) and 26°12'56.51" E (Longitude), and serves as the installation site for this research [17]. According to the Solargis map, the daily average global horizontal radiation for Bloemfontein is in the order of 5.6 kWh/m^2/day [18]. Bloemfontein's annual rainfall is in the order of 550 mm [19], which occurs mainly in the summer season. Annual summer temperatures can exceed 30ºC with dust storms being experienced on occasions [20].

Another key characteristic of Bloemfontein is its free roaming pigeons. According to an article in the Farmers Weekly in May 2013, pigeons that nest in and around Bloemfontein will fly up to 40 km to feed on sunflower fields in the vicinity, causing massive losses to local farmers [21]. This statement highlights a challenge faced by the agricultural society of Bloemfontein when it comes to the eating habits of pigeons. The challenge faced in electrical engineering is a little different, as it focuses not on what the pigeon eats, but rather on the actual presence of the pigeon and what it leaves behind.

IV. Research Methodology and Practical Setup

An experimental research design was used and can be seen in the block diagram in Figure I.

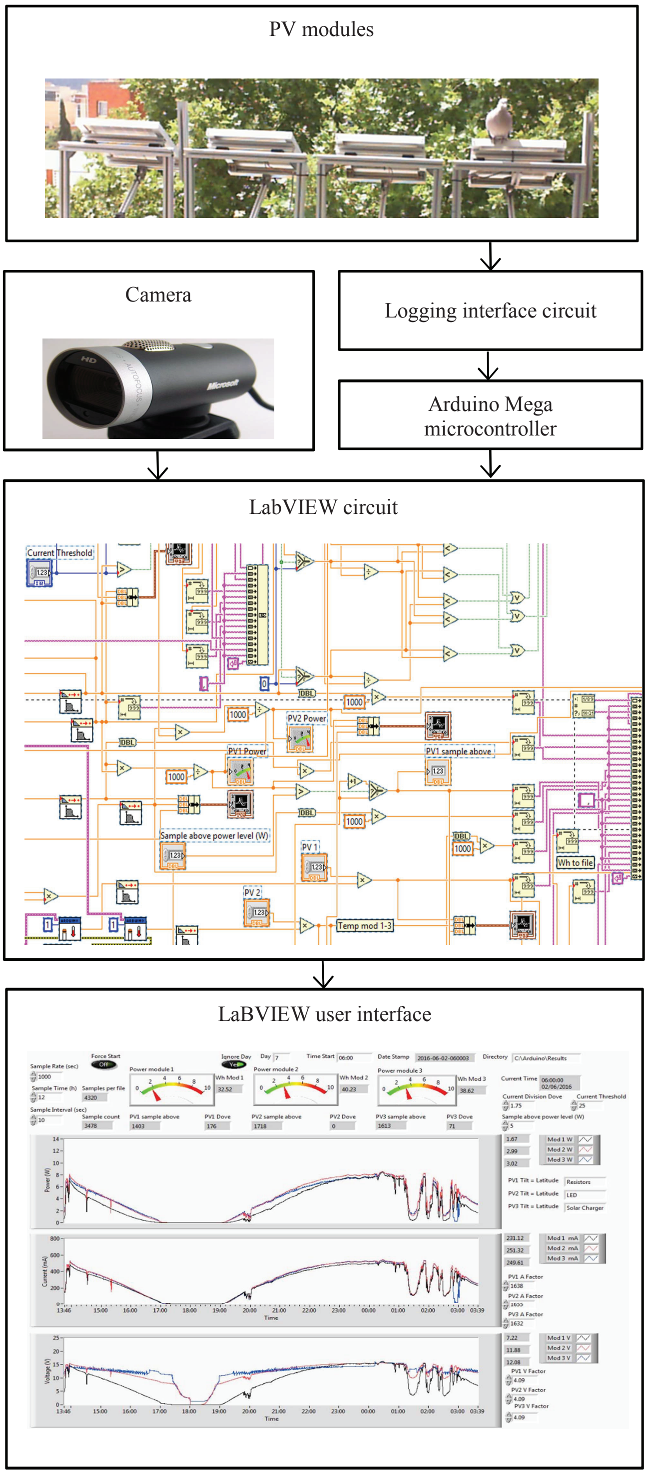

Figure I: Practical setup

The practical setup consisted of three identical PV modules connected to identical solar chargers, each with its own 12 V battery. The same power load (9 W LED lamps) was connected to each solar charger. The PV modules were installed at an orientation angle of 0° North, and at a tilt angle of 29°. These values are based on previous research done by the authors on pico-solar systems [22, 23].

The first block in Figure I represents the PV modules that is monitored by the system (a pigeon is visible in the right-hand module).

The second block of Figure I represents the logging interface circuit that provides power conditioning between the PV modules and the logger (third block representing the Arduino MEGA board). An image of the logging interface circuit and the logger is shown in Figure II. The analogue to digital converters of the Arduino is used to read the current and voltage values of each PV module. Voltage measurements are derived from a voltage divider circuit (147 kΩ resistor that is coupled in series with a 100 kΩ resistor) which is then multiplied by a calibration factor to obtain the correct value. Current measurements are recorded by measuring the voltage across a precision resistor (10 Ω 10 W 1%) and then multiplying it by a calibration factor to obtain the correct reading.

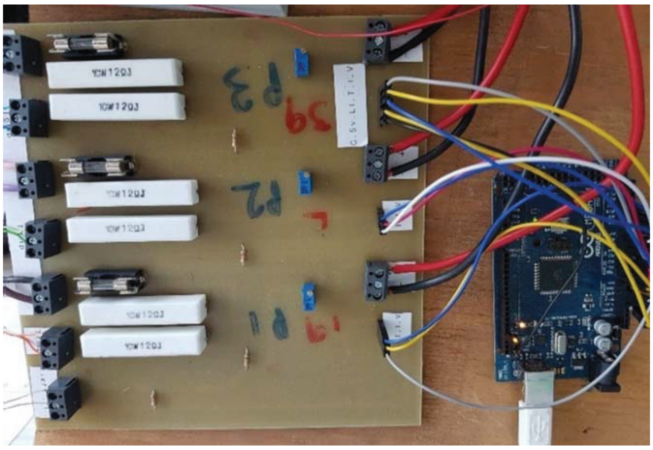

Figure II: Arduino board and logging interface circuit

The forth Block represents the LabVIEW circuit. The circuit represents a complex program, and only a small part of the actual circuit is visible in Figure I.

The fifth block in Figure I represents the LabVIEW user interface that is coupled via a USB cable to the Arduino via the LabVIEW circuit. This interface is shown in Figure IV and displays the current (B), voltage (C) and calculated power (A) for each module. The LabVIEW system records data at a sample rate of 10 seconds, storing it in a text file that is saved on the host PC. If a significant drop in the current drawn from one of the modules is detected, while the other modules output current stays the same, then the system logs the amount of time in 10-second intervals that this event occurs. An event can be seen in Figure IV (E) where only one of the three PV modules recorded a significant drop in current. Each 10-second interval causes the system to trigger a Webcam that captures and stores an image of the PV installation. The Webcam forms the final block of the practical setup.

The vision acquisition section in LabVIEW is responsible for communicating with the Webcam, and must be configured in accordance with the specific hardware (Figure III shows the structure which was used in LabVIEW). The Webcam that was used is a Microsoft LifeCam USB High Definition (720p) camera. The vision acquisition section then assigns a file name and time stamp to the image, storing it in a predefined folder on the hard drive. The images are then reviewed to verify the presence, or absence, of a pigeon on the PV modules.

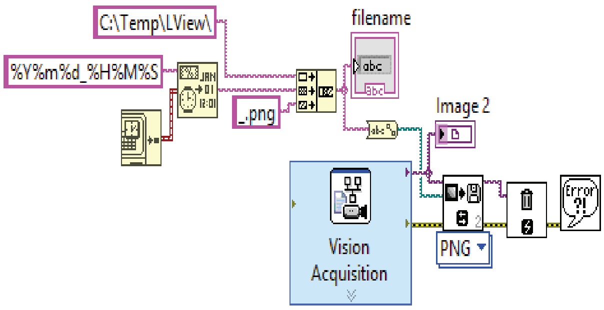

Figure III: LabVIEW code that captures and store a photo of the PV modules

V. Results and Discussion

The purpose of this paper is to present the design and results of a LabVIEW software system that was used to detect the presence of pigeons on PV modules in a pico-solar system. The presentation on the design of the system has been done in the previous section. This section presents the results of implementing the designed system.

The system was first implemented in November 2016, to resolve any issues or concerns. At that stage, an entry level Webcam was being used that did not provide quality images for evaluation purposes. A new higher quality Webcam (Microsoft LifeCam) was then installed, which provided better quality images. The system could now be evaluated in terms of detecting pigeons on the PV module.

The time period of interest is therefore from 2 January 2017 to 28 February 2017. In that period the system detected a total of 8 pigeons, with 140 images being taken, each representing an event for every 10-second intervals (sampling time set in LabVIEW). Of the 140 images, 121 (86.4%) were verified to have pigeons in them. This was determined by manually inspecting each image in Windows explorer. An example of such an image showing the presence of a pigeon is presented in Figure V. An analysis of the remaining images revealed that 7.8% showed no pigeons to be present on the PV modules. This would equate to the 10-second interval between events where the pigeon leaves the PV module. The drop in current caused by the initial presence of the pigeon has not yet been rectified in the system, as a short time delay exists between the actual event and it being recorded by the system. Six of the remaining images (4.3%) were identified to be isolated thick clouds (see Figure VI).

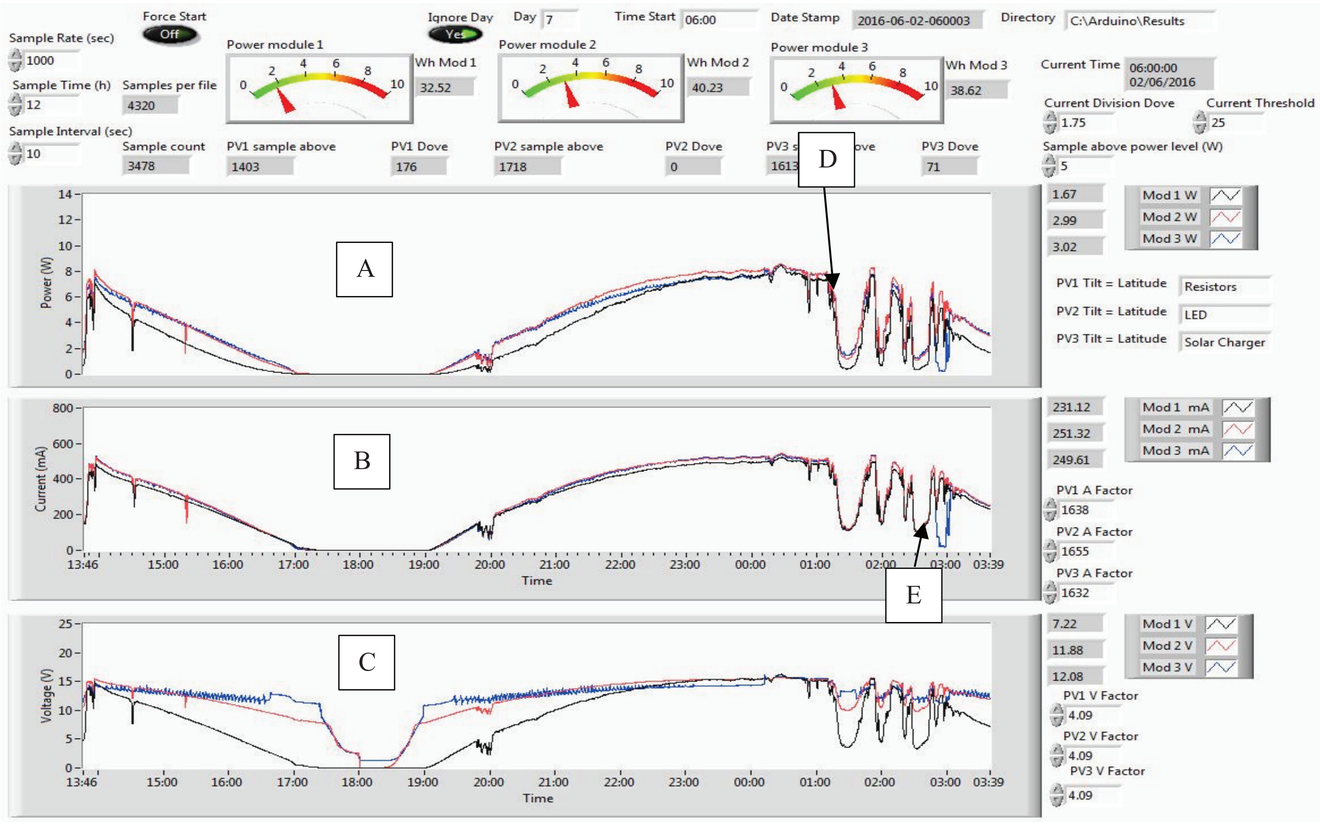

Figure IV: LabVIEW user interface

A slow moving thick cloud can shade one of the modules at a time, without shading the rest of the modules, thus triggering an event. Isolated thick clouds may not always trigger an event. An example of this can be seen in the user interface shown in Figure IV (D), where cloud movement caused a simultaneous drop in current and power for all three PV modules. A valid reason could not be found as to why the system recorded two of the 140 images. This represents an overall percentage of 1.4% (see Figure V).

Figure V: Image with pigeon clearly visible on the right hand side

Figure VI: Image with isolated thick clouds in the background

The results of correlating the images to the events are summarized in Table I, where the first two columns indicates the date and time of the recorded events. In the third column, the two events that could not be explained are shown. The forth column indicates the number of 10-second intervals where the event was caused by isolated thick clouds. In the fifth column, the number of 10-second intervals associated with the presence of pigeons on the PV modules is shown. The last column presents the number of events that occurred directly after the pigeon left the PV module, which is an indication of the short time delay of the system as it returns to normal operation after a severe current drop.

Figure VII: One of the two images where no reason for the event could be identified

Table I: Number of events and time of occurrence

Date	Time	Random event	Cloud events	Pigeon events	Missed events at the end
21-Jan-17	9:05	0	0	6	1
25-Jan-17	9:21	0	0	8	2
26-Jan-17	9:02	2	0	0	0
26-Jan-17	10:35	0	0	18	1
16-Feb-17	12:38	0	0	20	1
18-Feb-17	8:30	0	0	1	2
22-Feb-17	14:33	0	0	46	0
25-Feb-17	8:39	0	0	2	2
25-Feb-17	9:30	0	0	20	2
26-Feb-17	13:41	0	2	0	0
26-Feb-17	13:58	0	2	0	0
26-Feb-17	14:04	0	2	0	0
	Total	**2**	**6**	**121**	**11**

VI. CONCLUSIONS

The purpose of this paper is to present the design and results of a LabVIEW software system that was used to detect the presence of pigeons on PV modules in a pico-solar system. Results show that 86.4% of the recorded images reflected the presence of a pigeon on one of the three PV modules. 7.8% of the images were related to the 10-second interval where the pigeon leaves the PV module. 4.3% of the 140 images were evaluated to be caused by isolated thick clouds that shaded only one of the three PV modules. The remaining 1.4% of the images could not be explained. The detected pigeons spent an average of 2.5 minutes on the modules and the maximum time spend were 7.6 minutes.

Wrong identification of pigeons due to isolated thick clouds is a shortcoming of the system that can be addressed in future research. Another recommendation relates to lengthening the time period of the study to one year, to try and ascertain the frequency of when pigeons are present on the PV modules. Lastly, developing some type of intervention that will cause the pigeons to leave the PV module in a shorter time should be researched. This could lead to shorter interruptions of the direct beam radiation (also reduced times where the output power is lower than what is expected) and reduced hot spots in the PV modules due to lengthy shading times. Less time spend on the modules by the pigeons should also mean lower amounts of droppings that will cause static shading.

By the use and further development of the pigeon detection system described in this paper, the negative effects associated with the presence of birds near a PV installation may be reduced. This will enable an improved yield of energy from these PV modules that constitute a pico-solar system.

REFERENCES

[1] M. R. Maghami, H. Hizam, C. Gomes, M. A. Radzi, M. I. Rezadad, and S. Hajighorbani, "Power loss due to soiling on solar panel: A review," *Renewable and Sustainable Energy Reviews,* vol. 59, pp. 1307-1316, 2016.

[2] P. Bulanyi and R. Zhang, "Shading analysis & improvement for distributed residential grid-connected photovoltaics systems," in *The 52nd Annual Conference of the Australian Solar Council*, 2014.

[3] E. Yfantis and A. Fayed, "A camera system for detecting dust and other deposits on solar panels," *Advances in Image and Video Processing,* vol. 2, pp. 01-10, 2014.

[4] K. Ş. Parlak, "PV array reconfiguration method under partial shading conditions," *International Journal of Electrical Power & Energy Systems,* vol. 63, pp. 713-721, 2014.

[5] T. Ghanbari, "Permanent partial shading detection for protection of photovoltaic panels against hot spotting," *IET Renewable Power Generation,* 2016.

[6] A. Larsen and P. Lindquist, "Forecasting mismatch losses: An empirical study investigating module level inverter-and string inverter systems," 2014.

[7] K. Kim and P. T. Krein, "Hot spotting and second breakdown effects on reverse IV characteristics for mono-crystalline Si Photovoltaics," in *Energy Conversion Congress and Exposition (ECCE), 2013 IEEE*, 2013, pp. 1007-1014.

[8] M. G. Hudedmani, G. Joshi, R. Umayal, and A. Revankar, "A Comparative Study of Dust Cleaning Methods for the Solar PV Panels," *Advanced Journal of Graduate Research,* vol. 1, 2017.

[9] J.-L. Wybo, "Large-scale photovoltaic systems in airports areas: safety concerns," *Renewable and sustainable energy reviews,* vol. 21, pp. 402-410, 2013.

[10] M. Kacira, M. Simsek, Y. Babur, and S. Demirkol, "Determining optimum tilt angles and orientations of photovoltaic panels in Sanliurfa, Turkey," *Renewable energy,* vol. 29, pp. 1265-1275, 2004.

[11] P. Tiernan, "Enhancing the learning experience of undergraduate technology students with LabVIEW™ software," *Computers & Education,* vol. 55, pp. 1579-1588, 2010.

[12] C. Elliott, V. Vijayakumar, W. Zink, and R. Hansen, "National instruments LabVIEW: a programming environment for laboratory automation and measurement," *Journal of the Association for Laboratory Automation,* vol. 12, pp. 17-24, 2007.

[13] D. Cucиureanu, C. Nituca, G. Chiriac, and D. Sticea, "Analysis of the photovoltaic panels currently in use in different locations," in *Electrical and Power Engineering (EPE), 2016 International Conference and Exposition on*, 2016, pp. 888-893.

[14] D. de Babline, T. Urmee, and J. Ally, "Prospects and problems of increasing electricity production from mid-size renewable energy generation on the South-West Interconnected System (SWIS) in WA," *Procedia Engineering,* vol. 49, pp. 57-65, 2012.

[15] J. Jeong, X. Jiang, and D. Culler, "Design and analysis of micro-solar power systems for wireless sensor networks," in *Networked Sensing Systems, 2008. INSS 2008. 5th International Conference on*, 2008, pp. 181-188.
[16] S. K. Mulaudzi, M. Muchie, and R. Makhado, "Investigation of the solar energy production and contribution in South Africa: research note," *African Journal of Science, Technology, Innovation and Development: Building technological capabilities in solar energy in Africa,* vol. 4, pp. 233-254, 2012.
[17] Central University of Technology. (2014, 19 May). *Homepage*. Available: http://www.cut.ac.za/
[18] (2017). *Solargis-South-Africa-GHI-solar-resource-map-en.png (900Ã 816)*. Available: http://solargis.com/assets/graphic/free-map/GHI/Solargis-South-Africa-GHI-solar-resource-map-en.png
[19] M. N. Dingaan and P. J. Du Preez, "Grassland communities of urban open spaces in Bloemfontein, Free State, South Africa," *koedoe,* vol. 55, pp. 01-08, 2013.
[20] Eco Impact. (2015, 11 May). *Bloemfontein Dust Storm!* Available: http://www.ecoimpact.co.za/bloemfontein-dust-storm/
[21] A. Coleman. (2016). *Pigeons and doves pose a threat to grains*. Available: http://www.farmersweekly.co.za/agri-news/south-africa/pigeons-and-doves-pose-a-threat-to-grains/
[22] P. E. Hertzog and A. J. Swart, "Validating the optimum tilt angle for PV modules in a semi-arid region of South Africa for the winter season," in *ECTI-CON 2016*, Chiang Mai, Thailand, 2016.
[23] A. J. Swart and P. E. Hertzog, "Validating the acceptance zone for PV modules using a simplified measuring approach," presented at the ECTI-CON, 13th International Conference on Electrical Engineering, Electronics, Computer and Information Technology, Chiang Mai, Thailand. ISBN: 978-1-467-39749-0, 2016.

Pierre Hertzog received his DTech: Electrical: Engineering degree in 2004 from the Central University of Technology. His research interests include alternative energy and engineering education. He is currently an Associate Professor at the Central University of Technology.

James Swart received his DTech: Electrical: Engineering degree in 2011 from the Vaal University of Technology. His research interests include engineering education and alternative energy. He is currently an Associate Professor at the Central University of Technology.