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Pigeon Presence on PV Modules ARE Largely Random Events

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Abstract-: ***The presence of pigeons on PV modules can negatively affect the output power of a solar renewable energy system. The body of the pigeon itself (and especially the tail) may cause short periods of shading of individual cells, leading to the formation of hotspots. Bird excreta left by the pigeon may cause longer periods of shading, leading to an extended reduction in output power. Some type of intervention may be required to repel pigeons from PV modules, in order to try and maintain the overall efficiency and sustainability of a system. The purpose of this paper is to evaluate the reduction in output power of a pico-solar system in order to determine if a possible pattern, or routine, exists with regard to the presence of pigeons. A 10 W pico-solar system was installed in a semi-arid region of South Africa that is home to the feral pigeon (Columba livia). A pigeon detection technique was developed and applied over a period of 13 months to determine when and for how long these pigeons rest on top of a PV module (these are referred to as events). Although these events are primarily random in nature, results do indicate that feral pigeon presence is lowest on a Wednesday during the week and in the summer periods of January to March during a calendar year. They tend to spend, on average, 118 seconds perched on top a PV module, where their tail and droppings cause the most significant impact in terms of interrupting the direct beam radiation from the sun for an individual cell. It is recommended to use these results in formulating an appropriate intervention that may be used as a scare tactic to repel feral pigeons away from PV modules.***

Keywords: Arduino; LabVIEW; semi-arid; power reduction; renewable energy;

I. INTRODUCTION

Research into improving the performance and overall efficiency of renewable energy systems continues to be made in an effort to enhance sustainability. Sustainability is defined as “the ability to be maintained at a certain rate or level” and as “avoidance of the depletion of natural resources in order to maintain an ecological balance” [1]. When applied to a renewable energy system, sustainability can be defined as the ability to produce the minimum energy needs of a consumer over a prolonged period of time with no power interruptions. This really means maintaining an acceptable state of charge (SoC) for the energy storage system that often employs batteries. This, in turn, requires harvesting as much solar energy as possible during the day from a given PV system in order to re-charge the batteries that were used during the night to a 100% SoC before the next discharge period starts.

However, interruptions to the direct beam radiation of the sun often occurs, caused by cloud movement, trees or birds. This results in shading of PV modules or cells that result in a significant reduction in the amount of solar energy harvested [2]. One type of bird that can cause an entire cell in a pico-solar system to be shaded is the common pigeon or dove (a pico-solar system is defined as a renewable energy system where the output power is less than 10 W [3]).

Feral pigeons (Columba livia) are descended from rock doves (Columba livia), a Eurasian species which roosts and nests on natural cliffs [4]. Feral pigeons have gained the reputation of being a major urban pest [5], especially in terms of their excreta that soils facades and that can cause health risks to both humans and animals. In fact, pigeon excreta can contain certain fungus and bacteria that can lead to different airborne diseases [6]. It has also been reported that bird excreta, combined with humidity, can cause power line outages in transmission lines in Mexico [7]. It can also lead to the interruption of direct beam radiation from the sun, causing partial shading of a PV module [8] that can lead to the formation of hotspots, as a large number of series connected cells are affected by a singular shaded cell. This may force an entire string of cells to operate at a lower output power than desired [9], leading to accelerated cell degradation and lower system performance [10].

The purpose of this paper is to evaluate the reduction in output power of a pico-solar system in order to determine if a possible pattern, or routine, exists with regard to the presence of pigeons in a semi-arid region of South Africa. This may have an impact on the design of an intervention that may be used to repel the pigeons from a PV module. The current state of feral pigeons in the provincial capital of the Free State Province in South Africa is firstly reviewed. This is followed by the practical setup and research methodology that was followed in this study. Results and conclusions round off the discussion.

II. FERAL PIGEONS IN BLOEMFONTEIN

Two studies were identified from the literature focusing on feral pigeons at university campuses in South Africa. The first study explored the perceptions of 246 staff members employed on the Muckleneuk campus of the University of South Africa (UNISA) to ascertain the extent and nature of the perceived pigeon problem with suggested control methodologies [11]. UNISA is located in Pretoria in the Gauteng Province of South Africa. The second study considered the breeding behavior and success of feral

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pigeons in the Bloemfontein urban area, with special focus on the Sasol library building on the campus of the University of the Free State (UFS) [12]. In the latter study, it was found that out of 477 eggs, 262 successfully hatched in just one year on the top two floors of the library. This well illustrates the potential for thousands of hatchlings every year, when considering that the average land size of Bloemfontein is 236,7 km2 [13] while the library only covers an area of 0,004 km2.

The breeding activities of feral pigeons in the Bloemfontein urban area occur throughout the year, with a decrease during the late summer months (January through early March) when seasonal rainfall in the region reaches a peak [12]. Since the diet of these feral pigeons consists almost exclusively of field crops, the birds by implication have to leave the city limits regularly to feed [14]. More than other bird species, feral pigeons exhibit a behavior of short term resting, in the form of perching on elevated spots [15]. This would include the Sasol library on the main campus of the UFS (top floor is 16 m above the ground) and the ETB Building on the main campus of the Central University of Technology (CUT) (top floor is 15 m above the ground).

Numerous techniques have been suggested to repel feral pigeons from specific areas. While mechanical, chemical and acoustic repellent methods appear to be of little use, trapping and poisoning pose issues of social acceptability, as well as ecological efficacy [16]. The most effective method appears to be the denial of food [17]. Two specific techniques exist that were identified in the UNISA study mentioned previously, being lethal and non-lethal techniques. Lethal control strategies include shooting, poisoning and trapping [11] along with the use of falcons [18]. Non-lethal control strategies are generally directed at the pigeons' visual, auditory and tactile senses; however, habitat modification and reduction of pigeon presence can also be achieved by physical barriers [11].

Whatever non-lethal strategy is used, it must be noted that the continuous use of such an intervention to repel pigeons away from a specific area may become redundant after a while. Scare tactics, such as aluminium plates and strips of foil flapping in the wind, have limited effectiveness, as birds become used to these devices [19]. It has furthermore been reported that scaring devices that are not accompanied by a threat to the life of a bird or a risk that it may be injured, ceases to function effectively after a few days as the birds become used to them [20]. Birds also become used to acoustic and visual devices that are employed to repel them [7]. It has been suggested to rather consider combining a number of different strategies to repel birds, or feral pigeons, from a specific area [7]. However, a possible pattern, or routine, that is followed by feral pigeons should firstly be determined before designing such an intervention.

III. PRACTICAL SETUP

A block diagram of the practical setup that was used in this research to determine a possible routine for feral pigeon presence on a 10 W PV module is shown in Figure I. Three identical 10 W PV modules were directly connected to 9 W LED lamps (serving as the load resistance) via a data logging interface circuit (DLIC). To reduce the number of variables in this setup, no batteries or solar chargers were used. In previous research by the authors, LED lamps were identified as suitable loads for PV modules in a pico-solar system [21]. Output pins from the DLIC are connected to an Arduino Mega microcontroller that communicates the measured values to a LabVIEW program. This system will now be discussed.

Three 10 W polycrystalline PV modules (PV1, PV2 and PV3) were mounted on the same aluminium structure at a tilt angle of 29° (see Figure III), which is also the latitude of the research site As the research site is in the southern hemisphere, the orientation angle of the PV modules was 0° North.

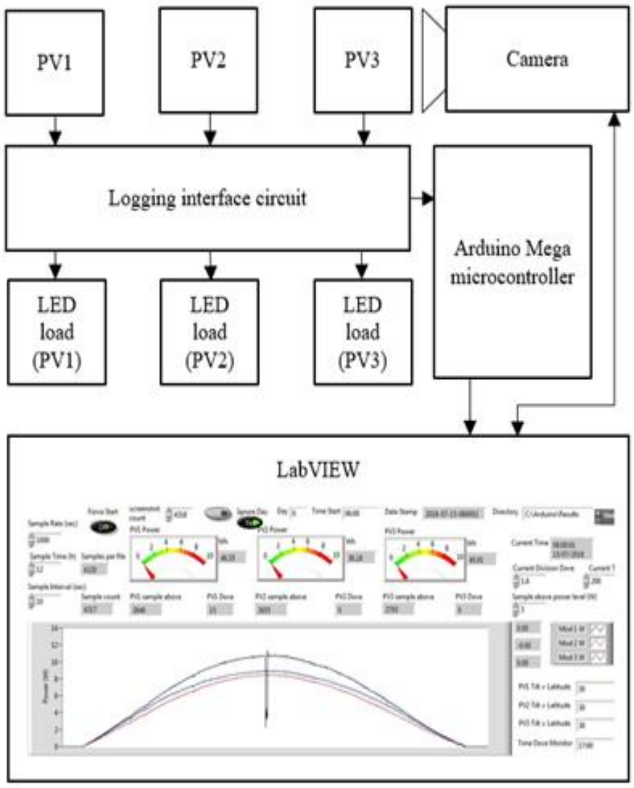

Figure I: Practical setup

A DLIC was used to measure the output voltages and currents of the three PV modules. The circuit consists of three identical sections (for the purpose of this discussion, only the circuit connected to PV1 is discussed (marked with red in Figure II). This DLIC consists of a voltage divider (potentiometer R1) that is used to measure the voltage across the PV module. A voltage divider is used in order to stay within the 0 to 5 V range of the analog to digital converter (ADC) of the Arduino (maximum power point voltages of the PV modules are around 16.5 V that will damage the input port to the Arduino). The current was determined by measuring the voltage across two parallel 12 ohm 10 Watt precision resistors (R7 and R8). These high power resistors are capable of handling the maximum power point current of the Pv module, that is rated as 610 mA. Both the current and voltage measurements were calibrated in the LabVIEW program by using a multiplication factor. The importance of regularly calibrating the voltage and current measurements of a pico-solar system was discussed by the authors in a different research paper [22]. A 10 000 ohm thermistor (T1) can also be seen in the circuit in Figure II that was used to measure the surface temperature of the PV module.

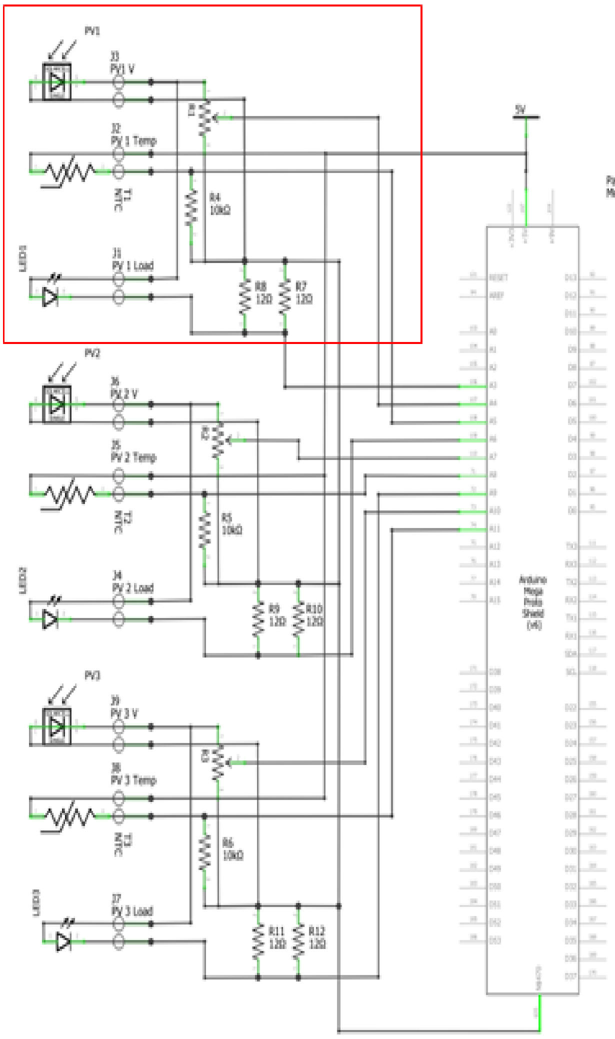

Figure II. Logging interface circuit

The ADC on the Arduino Mega was used to convert the analog voltages to digital values that could be used for mathematical calculations in the LabVIEW program. These calculations include Watt hour (Wh) values for a given sampling period, instantaneous power values and a counter to indicate the presence of a pigeon.

In the LabVIEW program, the Arduino Mega is set up as a slave, where the user interface (called the Front Panel) can display the voltage and current curves, along with a calculated power curve highlighting the performance of the 10 W PV module. The presence of feral pigeons on the PV modules is determined by monitoring the current curve for each module. As soon as the current of one module dips relative to the other modules, the program activates a USB camera (Microsoft LifeCam 720p) that takes an image of the modules. Dips in the current curve are used as the current varies drastically, and much more, than dips in the voltage curve that are caused by partial, or full, shading of the PV module. This image is stored so that the presence of a feral pigeon can later be verified by inspection. As an example, Figure III shows an image that was taken by the system on 2 March 2019 where the presence of two feral pigeons are visible.

Figure III: Image taken on 2 March 2019 by the Microsoft LifeCam 720p USB camera

The LabVIEW program also records the number of samples (each being 10 seconds in duration) where the current curve has dipped significantly. 4320 samples are recorded each day from 6 am to 6 pm in 10-second intervals. This data is then used to calculate the exact time that a feral pigeon perched on top of a PV module. The LabVIEW program was designed as an energy monitoring and recording system with a user interface that can be seen in Figure IV. An image of the LabVIEW user interface that represents one day of monitoring (2 May 2019) is evident (see point C for the date).

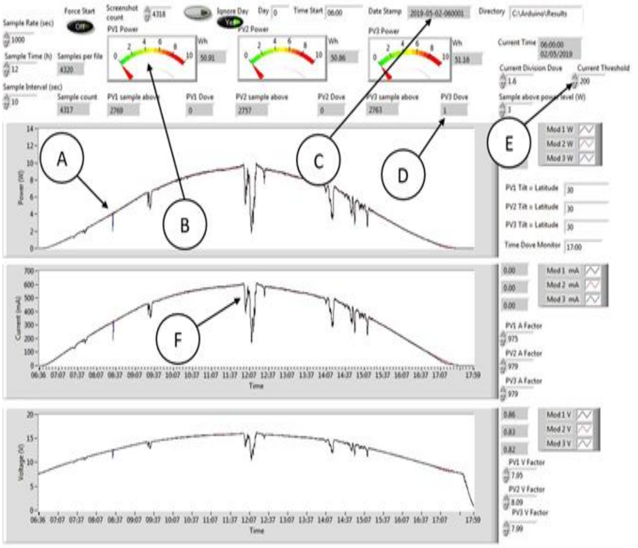

Figure IV: LabVIEW user interface

A dip in the current curve that was caused by a feral pigeon can be observed at about 08h30 in the morning (point A). The feral pigeon perched on PV3 for 10 seconds (one sample count was recorded – point D). Variations in output power of a PV module can also be caused by cloud movement, as can be seen at point F, where the current curve of all three PV modules dip at the same time. However, when the current of only one PV module dips, it is then associated with the presence of a feral pigeon and is recorded as an event. The current dip threshold can directly be set by the researcher on the user interface (point E). The researcher can also visually ascertain the instantaneous output power of the PV module (point B). At the end of the sampling period, the recorded data is stored in a text file. The stored data includes the total Wh for the day, the amount of 10-second intervals that pigeons were present on each individual module, and the maximum and minimum PV module surface temperatures.

IV. RESEARCH METHODOLOGY

The purpose of this paper is to evaluate the reduction in output power of a pico-solar system in order to determine if a possible pattern, or routine, exists about the presence of pigeons in a semi-arid region of South Africa. An experimental research design is used with a longitudinal study. Experimental designs are widely regarded as the most effective way to identify and gauge causality [23]. According to the Oxford English dictionary, causality is defined as "the relationship between something that happens and the effect it produces" [1]. In this research, causality relates to the relationship between the presence of the feral pigeon perched on top of a PV module and the subsequent reduction in output current that negatively affects the output power of a PV module. Longitudinal studies are often used in social sciences to conduct continuous and repetitive measures in order to track certain individuals over an extended period [24]. However, they can also be applied to engineering where one can track the continuous performance of a technology over an extended period of time, as it is exposed to various elements or environments.

This study was conducted over 396 days from 1 May 2018 until 31 May 2019. Three 10 W PV modules were installed at a tilt angle of 29° with a 0° North orientation. A DLIC was used in conjunction with an Arduino Mega to sample and communicate voltage and current values to a LabVIEW program. Current curve dips of individual PV modules were recorded as events and then correlated to the presence of feral pigeons by using the images obtained from a USB camera. The time that these pigeons perched on top of a PV module is calculated by multiplying the number of recorded events with 10 seconds. This data was analysed for the period of the study and is discussed in the next section.

V. RESULTS

During the study of 396 days, feral pigeons were detected to be perching on top of the PV modules for a combined total time of 18 hours and 44 minutes. The average time that a feral pigeon perched on a module was 118 seconds. This relatively short period correlates well with other research that states that feral pigeons exhibit a behavior of short term resting in the form of perching on elevated spots [15]. This result was confirmed by correlating the number of current curve dips for a given day to the images recorded by the USB camera. This process was detailed by Hertzog and Swart in 2017 [8].

The recorded data was then analyzed to determine if the presence of the pigeons were influenced by human movement in the vicinity of the practical setup. This analyzes would help to determine if a pattern or routine exists over a period of one week where much human movement occurs between Monday and Friday. This result is shown in Figure V. As can be seen, the highest occurrence of 20% was on Sundays. However, it is only 2% higher than on Friday, where 18% was recorded. The lowest percentage of events occurred on Wednesday (7%). However, no real significant pattern, or routine, could be derived when the rest of the weekdays are considered. It can thus be concluded that human presence did not significantly influence the presence of pigeons on the PV modules under test at this research site.

The question may also be asked if the presence of pigeons on the PV modules may be seasonal? To investigate this possibility, the average monthly presence of pigeons on the PV modules were analyzed (see Figure VI). As can be observed, the highest percentage of pigeon presence on the PV modules were recorded in June and in May of 2018 (13%). The lowest percentage was recorded from January to March 2019 (3%). This finding is in line with a study done on the main campus of UFS, where it was found that the breeding activities of feral pigeons decrease during the late summer months [12]. This would indicate that feral pigeons would be less active during January, February and March, as also indicated by the 3% of recorded events.

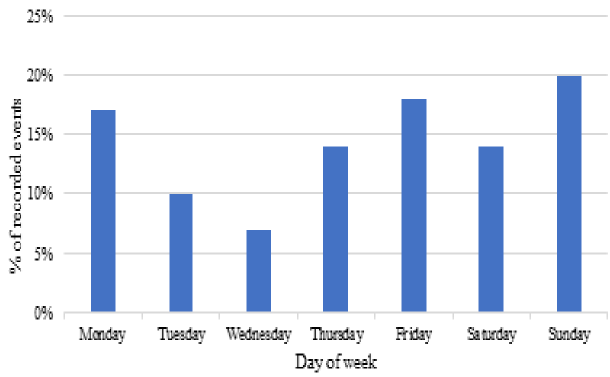

Figure V: Percentage of total occurrences of pigeon presence on PV modules during the week

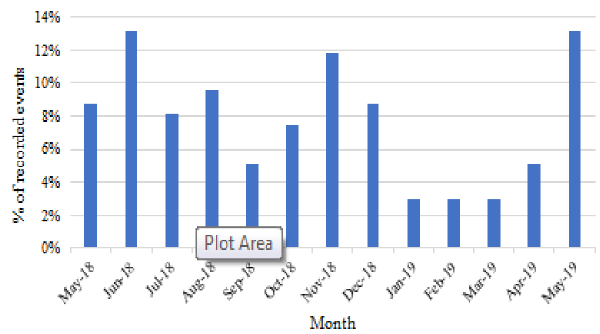

Figure VI: Monthly present of pigeons on the investigated PV modules

No other significant observations were made regarding the presence of pigeons relating to the month of the year. An extensive study, including several years of data, may be needed to better identify a pattern or routine of feral pigeon presence on PV modules.

VI. CONCLUSIONS

The purpose of this paper was to evaluate the reduction in output power of a pico-solar system in order to determine if a possible pattern, or routine, exists with regard to the presence of pigeons in a semi-arid region of South Africa. The reduction in output power that is linked to a dip in the output current curve of an individual PV module was recorded as an event. A number of random events occurred between 1 May 2018 and 31 May 2019 that indicated a low presence on a Wednesday during the week and in the summer periods of January to March (late summer months) during a calendar year. Feral pigeons in this area also tend to spend, on average, 118 seconds perched on top of a PV module, where their tail and droppings cause the most significant impact in reducing the output power of a 10 W PV module.

This research was limited to evaluating individual PV module current curve dips in terms of determining their frequency that may be related to a possible routine of feral pigeon presence. It did not consider the amount of power lost due to feral pigeons perching on top of a PV module. It did also not consider any possible interventions that may be used to repel feral pigeons from PV modules.

However, the results of this study may be used to formulate an appropriate intervention consisting of a number of scare tactic strategies that may be used to repel feral pigeons away from PV modules. This intervention should only be used when the pigeon is perched on top of a PV module, as pigeons may become use to the continuous use of an intervention that is permanently activated. It is therefore recommended to use the detection technique mentioned in this paper to activate some form of intervention during the months of April through December, when the presence of feral pigeons are higher than during the late summer months.

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