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Technical Note

Enhancement of a stand-alone photovoltaic system's performance: Reduction of soft and hard shading

Lisa A. Lamont*, Lana El Chaar

Petroleum Institute, Electrical Engineering Department, P.O. Box 2533, Abu Dhabi, United Arab Emirates

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ABSTRACT

A stand-alone photovoltaic (PV) system is the most promising solution to supply electric power to meet energy demand in isolated locations. This technology can offer an interesting alternative to other currently existing sources of energy. Due to space constraint in the remote offshore oil and gas industry, a stand-alone system is used for cathodic protection, telemetry and valve control. However in such an environment, dust accumulation and bird droppings have been critical issues to the operation of off-grid solar devices. These factors do not only reduce the available power of the modules but also makes the cost of solar devices ineffective since cleaning, especially on well-head towers, is very expensive due to the location. Hence this paper presents two technical solutions that have shown promising results in reducing the impact of these factors.

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1. Introduction

Low power electrical applications such as rural electrification or telecommunication stations can be vitally important for isolated communities. Grid-connection in such locations as remote offshore oil and gas industries or isolated desert areas are not always financially or technically viable [1]. For example connecting to the grid using subsea cable would add extensively to the installation cost and time. Hence, stand-alone systems are key options to increase systems' availability and meet load requirements. Historically diesel generators were commonly used for such purposes as water pumping and household electricity supply due to their low outlay cost and lack of other sources [1,2]. However, nowadays renewable energy sources in conjunction with these generators are options for certain applications. In this context one of the alternatives for this power supply based on the location of this research is solar energy. Solar energy, a clean source has a major advantage since it complies with the Kyoto Protocol in reducing the amount of CO_2 emissions which in turn has a great effect on the global warming. It can be harvested by means of solar collectors either thermally using concentrated solar power (CSP) or directly converted to electricity using Photovoltaics (PV). PV technology, even though an expensive option, can be deployed in remote locations where it is not economically feasible to extend to the grid [3,4] in addition to requiring minimal maintenance [2]. This technology is characterized by the capability of PV modularity allowing the designer to easily modify the system's capacity based on load requirements. In the oil and gas industry on the well-head towers where this research is undertaken hybrid combinations may not be a practical selection. Factors such as space, power, accessibility, and locations are limiting influences, making stand-alone PV arrays ideal for deploying. However, due to variations in the daily solar irradiation causing a changeable systems' power availability, off-grid PVs are often installed with backup battery banks ensuring constant supply for continuous device operation [5,6].

In the United Arab Emirates (UAE) where this work has been completed, climate and environmental issues have been proven to affect the PV systems' performance and such can be characterized into two main issues: – dust and birds. Onshore, dust in the desert region [7–10] and in particular the UAE has been proven to be a major problem for PV technology [11] opposed to bird droppings and shading which is mainly affecting offshore PV systems. Studies have verified that offshore platforms appear to be a stopover habitat for bird species [12]. The birds that use this as their habitation often not only leave behind their nests but also droppings on the cells (Fig. 1). Scientifically it has been determined that bird droppings contain many fungal agents, bacteria and ectoparasites potentially causing diseases in addition to health and safety issues

* Corresponding author. Tel.: +971 508190554; fax: +971 26075200.
E-mail addresses: llamont@pi.ac.ae (L.A. Lamont), lelchaar@pi.ac.ae (L. El Chaar).

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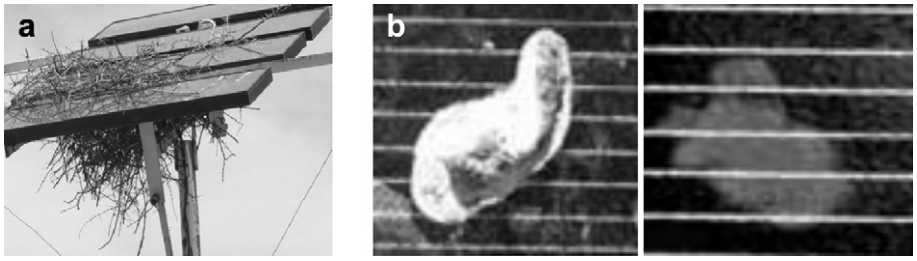

Fig. 1. a) Birds Nest, b) Bird Droppings.

including slipping therefore not only creating problems for PVs but for humans [13].

All of these issues create a shade that prevents the sun radiation from reaching solar cells. Hard shading due to bird droppings stops the light from reaching the cell which in turn prevents the module from converting any energy. Moreover, bird droppings contain highly corrosive uric acid that can damage metals and other materials when exposed for an extended duration [13,14]. The highlighted facts of dust and droppings are definite disadvantages that have a major impact on stand-alone PV systems' performance especially for difficult to access locations (well-head towers). Nonetheless, the unmatchable advantages these systems offer for locations where utility network is unavailable far outweigh the drawbacks. Consequently, integrating a cleaning solution would improve the stand-alone PV system's performance reliability.

2. Existing methods

There are several existing solutions to remove the dirt collected on solar panels. One of these solutions is a transparent shield placed on the solar panel [15]. This shield is connected to an electronic circuit powered by a single phase AC supply producing electromagnetic waves. The electromagnetic waves repel the dirt particles that are on the surface of the solar panel. Also, a microprocessor based device called "solar-wash" can be used to control the washing process of the panel. Another product is placing an Electro-Dynamics Screen (EDS) on the solar panel, which is composed of series of parallel electrodes on a substrate [16]. In addition, robotic cleaning mechanisms such as "Clean Ant Profi" [17] and the "Solarbrush PV Robot" [18] are also available. However, such systems are all still in the prototype stages or are not cost effective.

Table 1
Comparison of a selection of cleaning systems.

Cleaning System	Advantage	Disadvantage
Manual	Cleaning only when required	Cost varies depending on location and manpower Time consuming and inefficient
Transparent Shield [15]	No mechanical movement to scratch the protective surface	Requires high voltage for good performance. Causes shading when used on a PV panel Cannot be directly powered from the panel
Electro-Dynamics Screen (EDS-PV) [19]	Efficient and can be used to remove dust from a variety of surfaces	Requires 3-phase high voltage amplifier which is a problem in remote locations
Integrated Electro Dynamic Screens [20]	Efficient with and without use of external power supply	Requires a Digital Signal Controller (DSC) which is costly Requires switching devices for converters hence more maintenance is required
Standing Wave Electric Curtain [21]	It is highly efficient at high gas pressure	Removal is difficult when gas pressure is below a certain limit Dust removal capability depends on the size of the particles deposited
Solarbrush PV Robot [18]	Automated robot	Heavy weight and has a high initial cost Requires human intervention
CleanAnt [17]	Self regulating and flexible uninterrupted cleaning operations	Heavy and large Requires external source for charging
Over-dimensioned PV Array	More power available hence possible onshore implementation Acceptable initial investment	Limited space offshore Requires larger battery bank therefore higher losses

Table 2
Comparison of Cleaning systems.

System Description	PIC Based Cleaning [24]	PLC Based Cleaning [23]	Evaluation
Electrical	Microcontroller and logic circuit	Programmable Logic Controller (PLC)	Design 1 is cheaper and more compact
Mechanical	Pulleys and Belt	Gears and chain	Design 1 more suitable for offshore application due to material use
Cleaning Device	Wiper	Rotating Roller	Design 2 has shown better removal of dirt
Bird Deterring	Light Emitting Diodes at night and Wiper Movement and buzzer during the day	Sirens	A combination of both would be more efficient
Cleaning Initialization Method	Photodetector	Timer	Both can be easily changed to suit cleaning specifications
Water Supply	Integrated Solar Desalination System	Water Tank	Design 2 is cheaper and easier to install initially However, Design 1 over an extended period has proven superior
Components Cost	**US$ 900**	**US$ 1400**	

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