American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-9, Issue-8, pp-134-140
www.ajer.org
Research Paper Open Access

Investigation Into The Causes Of Solar Street Lights Failure In Nigeria

Asaolu G.O.[1], Oladele T.A.[2], Bamiduro H.A[3] and Abdulraheem T.[4]
Power Equipment and Electrical Machinery Development Institute, P.M.B 1029, Okene, Kogi State, Nigeria[1, 3,4]
Engineering Material Development Institute, Akure, Ondo State, Nigeria.[2]

ABSTRACT
Huge sums of money are being sunk by authorities at all levels in Nigeria into the installation of solar street lights which often fail shortly after installation. This study investigates the causes of solar street lights failure in Nigeria. Survey of some solar street lights installations, restoration of some failed ones and interviewing of some installers were carried out. The result of the investigation shows that failure and malfunctioning of solar street lights amongst other things are as a result of wrong sizing of components, shading of solar cells, accumulation of dust on the panels, wrong situation of batteries, use of sub- standard components and in some cases theft.

KEYWORDS: *street light, solar panel, charge controller, battery.*

Date of Submission: 07-08-2020 Date of acceptance: 21-08-2020

I. INTRODUCTION

Over the years, security posed a major concern to pedestrians and drivers at night due to total darkness. Many accident involving passenger buses at night are largely caused by poor visibility [1]. Street lights increase road safety at night and in bad weather. Socialization also increases with street lighting because an illuminated village invites people to the streets and can contribute to a decrease in rural exodus [2]. However, installations of street lights are often a major investment challenge, especially in areas where there are no established grid infrastructures. Solar Street light is an attractive alternative in this scenario [3]. It was initially used mainly in third world countries in remote areas where electricity is not available or supply is unreliable. Today's solar technology has evolved and solar projects are appearing in developed as well as developing countries [4]. They are beneficial because they have reduced running and maintenance cost, environmentally friendly and convenient to install [1].

Solar street lights are powered by solar panels which convert solar energy from sun into electrical energy saved in a storage battery during day time, which is then used to power lamps at night to produce illumination [2]. Many state and local authorities in Nigeria have installed solar street lights in their respective domain. But unfortunately, soon after installation, many of these solar street lights fail completely or become partially functional. A number of technical factors may be responsible for this failure.

Nigeria with her location on the equator is within a high sunshine belt where solar irradiation is fairly well distributed [5]. Irradiation refers to the cumulative solar energy striking a given surface within a given time. It is represented by the symbol "H"and measured in watt-hours per square metre (Wh/m^2). When designing a solar system for a particular location, it is important to know how much energy can be harvested in a day, a month or a year. Therefore, solar energy is measured in kilowatt hours per square metre per day ($kWh/m^2/day$), per month or per year [6]. It is estimated that the annual daily average total solar irradiation varies from about 12.6 $MJ/m^2/day$ (3.5 $kWh/m^2/day$) in the coastal region to about 25.2 $MJ/m^2/day$ (7.0 $kWh/m^2/day$) in the far north. [5]

II. COMPONENTS OF A SOLAR STREET LIGHT

Major components of a solar street lights are solar panel, charge controller, battery and lamp

2.1 Solar Panel

Solar panel is the electricity generating component of the system which converts sunlight into electric energy [6]. Solar panel is made up of photovoltaic (PV) modules. These modules themselves, having no moving parts are highly reliable, long lived and require little maintenance. In addition, PV panels are easy to assemble into an array of arbitrary size. The main disadvantage of PV is its high capital cost. Despite this, especially for small systems, PV is often a cost-effective option with or without another power source, as the savings of use pay back the initial cost [7]. The working principle of solar cells is based on the photovoltaic effect, by the generation of a potential difference at the junction of two different materials in response to electromagnetic radiation. The photovoltaic effect is closely related to the photoelectric effect, where electrons are emitted from a material that has absorbed light with a frequency above a material-dependent threshold frequency [8]. The individual PV cells that are wired together in series and in parallel to produce the desired voltage and current. The cells are usually encapsulated in a transparent protective material and typically housed in an aluminum frame [9].

PV modules are rated in terms of peak watts (Wp). This rating is a function of both panel size and efficiency. The rating scheme also makes it easy to compare modules from different sources based on cost per Wp. The Wp is the power that the module will produce under standard test conditions (1kW/m^2 of solar radiation and 25°C panel temperature). Thus, a module rated at 50 Wp will produce 50 W when the irradiance on the module is 1 kW/m^2 at 25°C [7]. However, because PV modules seldom work under standard test condition in the real world, they commonly range in size from 5Wp to 300Wp [6]. The most common type of commercially available PV module is the crystalline silicon PV module manufactured using either monocrystalline or polycrystalline silicon, with the former having the highest conversion efficiency. Another common type of PV module technology is amorphous silicon which is also called thin film. [6]. Amorphous cells are generally less efficient and may be less-long lasting, but are less expensive and easier to manufacture[7]. Some of the specifications of a panel include Open Circuit Voltage (Voc), Maximum Power Voltage (Vmp), Short Circuit Current (Isc) and Maximum Power current (Imp). Open Circuit Voltage is the maximum voltage a solar panel can ever produce when it has no load connected to it. Maximum power voltage is the voltage across a solar panel when it is producing maximum power to load under standard test conditions. Short Circuit Current is the maximum current a solar panel can produce when the terminals are short circuited while Maximum Power current is the amount current measured when a solar panel is producing maximum power.

2.2 Battery

Batteries are electrochemical devices that store energy in chemical form. They store excess energy for later use in order to improve system availability and efficiency. Batteries store the electricity from solar panel during the day and provide energy to the fixture during the night. [7]. There are two types of batteries, the starter and the deep cycle. These two differ by the depth of cycling (charging) that they can withstand. A typical use for a starter battery is in a motor vehicle. Starter batteries which are shallow cycle cannot sustain long periods of deep discharge but are primed to supply very large amounts of current instantaneously. Deep-cycle batteries are used in photovoltaic systems. They support long periods of deep discharge but cannot sustain high currents for long periods [6]. Battery lifetime is measured both in terms of cumulative energy flow through the battery (full cycles) and by float life. A battery is dead when it reaches either limit. For example, discharging a battery twice to 50% is one full cycle. Depending upon the brand and model, battery lifetimes vary widely, ranging from less than 100 full cycles to more than 1500 full cycles [7]. NiCads usually have longer cycle lives than lead-acid batteries. Temperature affects the battery capacity during regular use too, because the lower the temperature, the lower the battery capacity. The chemicals in the battery are more active at higher temperatures. The actual cycle life of a battery is shortened by deep discharges, high temperature, and too much discharging at a high rate [10].

2.3 Charge Controller

The charge controller protects the battery from over charging and disconnects the load to prevent deep discharge. It checks the state of charge of the battery between pulses and adjusts itself each time [11]. Since most batteries hardly recover after exceeding the maximum depth of discharge, the integration of controllers in PV systems prevents this occurrence thereby extending the service life of the batteries [10]. When a battery is being overcharged, it loses water by gassing. Since fully charged battery can no longer hold solar charge from the module, the charge causes a chemical reaction which changes water in the electrolyte to hydrogen gas which escapes from the electrolyte as bubbles [9]. Commercially available charge controllers come in two common types: Pulse-width Modulator (PWM) and Maximum Power Point Tracking (MPPT).The pulse-width modulation charge controller is the most common type. It operates using basic ON/OFF switching to regulate the charging voltage. Maximum power point tracking charge controller also referred to as maximum power point tracker is mostly used in systems larger than 1 kW. MPPT regulation is performed by scanning and locating the characteristic I-V curve of the photovoltaic array and determining the maximum power point. The

MPPT charge controller is more expensive than a PWM charge controller but it generally increases the energy output from the PV modules by up to 30% [6].

2.4 Lamp

Lamps provide the needed illumination by the application of the required voltage. They convert electric energy into light energy, which is also called visible radiation. Visible radiation is the part of the radiation spectrum that our eyes can detect. We can see visible radiation but we cannot see heat radiation or ultraviolet radiation. Efficient lamps give off a maximum of visible light while producing only a small amount of wasted heat. The most important factor in the choice of lamps is efficacy. Lamps that use more power require more solar cell modules to provide them with enough energy [9]. Lamps are of different types such as LED (light emitting diode), CFL(compact florescent lamp) and Sodium Vapour. LED lamps offer long life, high efficiency but with high initial cost compared with others [1]. LED lights are usually used for lightning source for modern solar lights. These lights provide much higher lumens with lower energy consumption. LED lights give energy consumption up to 50 percent lower than high pressure sodium lamp (HPS) which is widely used as lightning source in traditional street lights. [12]

III. METHODOLOGY

The methodology adopted for this work involved:

i. Examination of installed solar street lights through visual inspection.
ii. Making inquiries from installers on how they carry out components sizing and installations.
iii. Restoration of some faulty solar street lights to normal operation.

To find out whether insufficient irradiation is a factor responsible for poor performance of solar street lights, solar irradiation data of different locations cutting across all the geopolitical zones in Nigeria were gotten from the National Aeronautics and Space Administration (NASA). Table1. shows solar irradiation data of 22 years average from 1983-2005

Table 1: Monthly average solar irradiation incident on a horizontal surface at different locations in Nigeria [13]

		Monthly average Solar Irradiation incident on a horizontal surface (kWh/m^2/day)											
s/n	Town	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	Aba	5.53	5.59	5.32	5.09	4.72	4.31	3.85	3.77	3.94	4.27	4.84	5.29
2.	Abakaliki	5.77	5.86	5.65	5.34	5.05	4.66	4.29	4.06	4.39	4.74	5.22	5.45
3.	Abuja	5.88	6.09	6.27	6.06	5.58	5.06	4.44	4.19	4.73	5.31	5.98	5.81
4..	Akure	5.67	5.77	5.63	5.35	5.03	4.56	3.98	3.78	4.09	4.65	5.26	5.39
5.	Ankpa	5.82	5.89	5.78	5.44	5.11	4.68	4.40	4.19	4.41	4.77	5.39	5.56
6.	Azare	5.61	6.32	6.75	6.78	6.59	6.26	5.63	5.33	5.69	5.88	5.67	5.25
7.	Babana	5.63	6.10	6.28	6.28	6.00	5.40	4.83	4.62	5.08	5.62	5.87	5.73
8.	Baga	6.14	6.64	6.91	6.90	6.69	6.34	5.73	5.55	6.00	6.47	6.33	5.78
9.	Baro	5.80	5.96	6.07	5.88	5.50	5.05	4.66	4.42	4.71	5.26	5.80	5.69
10.	Bauchi	5.74	6.21	6.40	6.12	5.88	5.66	5.25	4.95	5.43	5.85	6.01	5.62
11.	Beli	6.12	6.30	6.17	5.78	5.41	4.94	4.64	4.50	4.77	5.20	5.80	5.89
12.	Benin City	4.39	4.77	4.79	4.78	4.69	4.28	3.54	3.47	3.88	4.41	4.82	4.38
13.	Biliri	5.93	6.29	6.38	6.22	5.85	5.36	4.82	4.55	4.99	5.52	5.94	5.71
14.	Birnin Kebbi	5.40	6.29	6.65	6.76	6.64	6.43	5.63	5.29	5.75	5.95	5.70	5.15
15.	Birnin Kudu	5.55	6.27	6.61	6.67	6.42	6.02	5.57	5.30	5.62	5.85	5.65	5.15
16.	Biu	5.79	6.26	6.51	6.34	6.04	5.65	5.14	4.91	5.32	5.70	5.84	5.50
17.	Bugama	5.24	5.13	4.73	4.50	4.09	3.45	3.11	3.42	3.22	3.60	4.18	4.77
18.	Bussa	5.73	6.27	6.02	6.13	5.75	5.17	4.65	4.38	4.83	5.39	5.73	5.71
19.	Calabar	5.50	5.70	4.97	4.62	4.32	3.60	3.19	3.11	3.26	3.63	4.29	5.05
20.	Damaturu	5.63	6.34	6.72	6.78	6.53	6.24	5.58	5.27	5.68	5.86	5.62	5.27
21.	Damboa	5.62	6.35	6.73	6.75	6.42	6.09	5.52	5.24	5.62	5.84	5.69	5.17
22.	Dan Gulbi	5.50	6.01	6.34	6.40	6.20	5.82	5.12	4.80	5.36	5.77	5.87	5.33
23.	Dikwa	5.52	6.38	6.91	6.95	6.67	6.36	5.80	5.42	5.60	5.71	5.49	5.07
24.	Dukku	5.69	6.15	6.40	6.24	6.08	5.70	5.35	5.08	5.46	5.84	5.85	5.52
25.	Enugu	5.68	5.74	5.57	5.25	4.94	4.54	4.14	3.91	4.19	4.57	5.11	5.40
26.	Gamboru	5.15	5.46	5.85	6.19	6.20	5.77	5.30	5.03	5.27	5.29	5.17	4.84
27.	Ganye	6.19	6.47	6.37	5.93	5.59	5.26	4.80	4.63	4.96	5.52	6.13	5.95
28.	Gashua	5.59	6.41	6.83	6.98	6.72	6.53	6.00	5.57	5.78	5.89	5.70	5.20
29.	Gassol	6.00	6.30	6.31	6.02	5.54	5.07	4.69	4.51	4.78	5.28	5.91	5.83
30.	Gombe	5.68	6.19	6.45	6.43	6.21	5.79	5.28	5.00	5.36	5.72	5.70	5.43
31.	Gumel	5.55	6.41	6.83	7.02	6.89	6.63	6.02	5.64	5.84	6.03	5.78	5.28
32.	Gummi	5.37	6.20	6.62	6.74	6.65	6.43	5.63	5.26	5.73	5.91	5.60	5.14
33.	Gusau	5.50	6.29	6.70	6.84	6.70	6.50	5.68	5.31	5.73	5.94	5.68	5.25
34.	Ibadan	4.51	5.34	5.54	5.70	5.28	4.89	4.45	4.11	4.63	4.95	4.94	4.46
35.	Ihiala	5.41	5.39	5.16	5.00	4.60	4.10	3.51	3.57	3.65	4.11	4.71	5.03
36.	Ijebu Igbo	5.32	5.48	5.37	5.21	4.79	4.15	3.88	4.04	3.96	4.44	4.95	5.17

37.	Isa	5.49	6.42	6.91	7.19	7.04	6.94	6.32	5.80	5.97	6.03	5.77	5.12
38.	Jalingo	6.16	6.47	6.40	6.06	5.59	5.06	4.62	4.43	4.77	5.32	5.97	5.99
39.	Jimeta	5.86	6.26	6.41	6.19	5.81	5.44	5.00	4.79	5.18	5.64	6.01	5.69
40.	Jos	5.99	6.25	6.35	5.98	5.45	4.95	4.47	4.21	4.64	5.28	6.12	5.83
41.	Kaduna	5.76	6.06	6.32	6.30	5.94	5.40	4.85	4.47	5.11	5.63	6.11	6.23
42.	Kangiwa	5.24	6.15	6.48	6.60	6.48	6.20	5.54	5.25	5.71	5.84	5.60	5.11
43.	Keffi	5.89	6.07	6.11	5.77	5.40	4.89	4.52	4.27	4.60	5.12	5.80	5.76
44.	Kishi	5.67	6.03	6.26	6.11	5.73	5.06	4.47	4.19	4.62	5.19	5.66	5.69
45.	Koko	5.19	5.78	6.17	6.30	6.17	5.83	5.14	4.86	5.37	5.77	5.65	5.21
46.	Kotangora	5.57	6.04	6.29	6.31	6.03	5.47	4.79	4.52	5.10	5.63	5.81	5.62
47.	kumagunam	5.51	6.40	6.89	7.17	7.01	6.83	6.38	5.96	6.01	6.10	5.80	5.23
48.	Lafia	5.90	6.15	6.15	5.75	5.35	4.88	4.48	4.28	4.58	5.13	5.87	5.87
49.	Lafiagi	5.74	5.91	6.01	5.78	5.43	4.92	4.44	4.26	4.55	5.12	5.72	5.67
50.	Lagos	5.28	5.49	5.46	5.21	4.76	4.04	3.95	3.98	4.09	4.55	4.95	5.17
51.	Lere	5.75	6.18	6.39	6.28	5.93	5.47	5.01	4.70	5.12	5.69	6.02	5.71
52.	Magumeri	5.58	6.43	6.85	6.99	6.70	6.47	5.96	5.54	5.71	5.89	5.62	5.24
53.	Maiduguri	5.61	6.30	6.70	6.62	6.36	5.97	5.43	5.14	5.57	5.89	5.84	5.35
54.	Makurdi	5.88	6.01	5.85	5.48	5.17	4.75	4.42	4.19	4.45	4.88	5.50	5.72
55.	Minna	5.72	6.01	6.26	6.12	5.73	5.17	4.64	4.36	4.82	5.42	5.85	5.73
56.	Mokwa	5.71	6.01	6.26	6.17	5.82	5.21	4.73	4.43	4.86	5.43	5.76	5.69
57.	Nguru	5.53	6.34	6.77	6.97	6.82	6.62	6.00	5.58	5.86	5.97	5.70	5.24
58.	Obudu	5.98	6.04	5.70	5.31	4.97	4.57	4.19	4.01	4.37	4.70	5.24	5.74
59.	Ogbomosho	5.67	5.84	6.02	5.71	5.37	4.82	4.21	3.95	4.33	4.89	5.47	5.58
60.	Okene	5.77	5.84	5.71	5.42	5.13	4.70	4.34	4.13	4.33	4.80	5.40	5.59
61.	Onitsha	5.56	5.60	5.39	5.16	4.86	4.44	3.94	3.82	4.04	4.50	5.06	5.32
62.	Oshogbo	5.57	5.74	5.66	5.34	5.02	4.51	3.89	3.73	4.06	4.62	5.18	5.37
63.	Pankshin	5.78	6.26	6.30	5.83	5.49	5.15	4.70	4.40	4.96	5.52	6.04	5.78
64.	Pindiga	5.81	6.26	6.33	6.19	5.89	5.45	5.03	4.77	5.09	5.62	5.94	5.78
65.	PortHarcourt	4.13	4.32	4.23	4.29	4.13	3.82	3.51	3.29	3.79	3.89	3.98	4.15
66.	Runka	5.45	6.22	6.64	6.82	6.63	6.35	5.65	5.28	5.60	5.83	5.62	5.19
67.	Shaki	5.63	5.87	6.02	5.73	5.43	4.78	4.12	3.8.6	4.22	4.76	5.38	5.56
68.	Shendam	5.87	6.17	6.21	5.86	5.39	4.93	4.59	4.35	4.66	5.19	5.86	5.87
69.	Tegina	5.68	6.09	6.31	6.30	5.99	5.37	4.68	4.34	5.03	5.58	5.95	5.71
70.	Ugep	5.61	5.66	5.35	5.09	4.78	4.36	3.89	3.69	4.01	4.32	4.84	5.33
71.	Warri	5.33	5.33	5.19	5.05	4.55	3.75	3.30	3.80	3.65	4.26	4.97	5.13
72.	Wudil	5.55	6.29	6.65	6.69	6.37	5.93	5.45	5.16	5.53	5.77	5.65	5.35
73.	Wukari	5.92	6.09	5.97	5.58	5.24	4.81	4.54	4.35	4.59	4.98	5.49	5.77
74.	Yelwa	5.64	6.02	6.24	6.29	6.08	5.50	4.92	4.71	5.19	5.66	5.78	5.73
75.	Zaria	5.52	6.17	6.49	6.56	6.26	5.86	5.31	4.94	5.42	5.73	5.71	5.34
76.	Zuru	5.41	5.97	6.30	6.40	6.23	5.88	5.14	4.80	5.40	5.81	5.77	5.36

IV. RESULTS AND DISCUSSION

Table1. Shows that Nigeria has solar irradiation suitable for solar street light installations because the least solar insolation of 3.11kWh/m^2/day can still effectively support the normal operation solar street lights. Hence, it can be deduced that insufficient irradiation cannot be said to be a reason for the incessant solar street lights failure. Thus, some technical and non-technical factors were found to be responsible for the failure. They are:

- **Wrong Sizing of components**

Inaccurate sizing of the system components can lead to gradual failure of solar street light. It was observed that in some cases, components were not rightly sized. For instance, installations that require a solar panel of 160 W to effectively power a solar street light with 36W lamp based on the irradiation of the location was found to have a solar panel of 80W capacity been installed. This 80W solar panel cannot supply the battery the required energy needed to power the lamp for the anticipated number of hours. For this case, the street light operates for just few hours, lesser than the required hours of operation.

- **Shading**

It was observed that some installations were made without considering the effect of shadow casting on the solar module by nearby buildings or trees. A solar street light close to a tree or building can make some of the cells that make up the panel to be shaded. Shading of a single cell will drastically reduce the output of the entire solar panel. Partial shadow has a great influence on the output characteristic of photovoltaic module. For a series of cells, the output current declines with the increase of blocked area percentage. The whole output current is decided by the output current of the cell which was blocked. There will be no current if the cell is blocked completely because the circuit is equal to an open circuit. Over 80% power loss may occur even though the area blocked by shadow is about 10% [14]. Reduction in the output power produced by a solar panel as a result of shading would affect the system because the battery would not be able to get the needed current to charge it properly. Figure 1 shows a case of an installation erected close to a tree that could lead to shading on the solar cells.

Figure 1: A solar street light installed very close to a tree.

- **Poor Maintenance practice**

Lack of maintenance is another factor that reduces the performance of solar street lights. After the street lights are installed, no any other maintenance work is carried out on it. For instance, regular cleaning of the solar panel is required to prevent accumulation of dust which adversely affects the output of a solar panel. Dust has a great influence on the efficiency of PV system and the power loss by dust could be as high as 30% of rated power [14]. During this study, it was also observed that cleaning of the terminals of the batteries was enough to bring back some faulty solar street lights to normal operation. Components such as lamps and batteries which have a life expectancy lower than that of a solar panel are not replaced when they go bad due to poor maintenance culture. Also, some installations were resuscitated by mere tightening of loose connections due to partial contact which made the street lights come on and go off intermittently.

- **Misorientation or wrong tilt angle**

The available solar energy depends on local latitude and modules orientation. This orientation is defined by azimuth (α) and inclination or elevation (β) angles. Although PV module produces more energy if it is able to follow the sun's path during the day using a solar tracking system, system cost will increase and the moving parts (tracker) will contribute to a lower system robustness, which can lead to a higher operation and maintenance cost. In a fixed system the module should be turned towards the terrestrial equator (facing south in the north hemisphere and north in the south hemisphere) [2]. Angle of inclination is the angle that the panel is facing up into the sky. The angle of inclination of a solar panel depends on the geographical location. For a solar street light, the optimal angle of inclination is the latitude of that location. But during this study it was observed that this rule was not followed in many instances.

- **Use of sub-standard product**

It was also been observed that some of the solar street lights components used by contractors were sub-standard and in some cases overrated. For instance, a test carried out on a solar panel with nameplate rating of 200W was found to be actually 80W. If such panel is installed considering the nameplate rating, it will lead to system failure because the panel would not be able to supply the needed current required to charge the battery optimally.

- **Wrong placement of Batteries and theft**

The batteries of some solar street lights were found to be wrongly situated. These installations have their batteries placed inside the street lights poles. Although this might look more appealing to the eye but it is technically wrong. This could result into increase in operating temperature of the battery which is detrimental to it. Figure 2 shows a case of a battery being placed in the pole. Also, battery theft is another reason for failure of some installations as it was observe that some street lights have their battery casings left open with no batteries inside them.

Figure 2: solar street lights with wrongly placed battery

V. CONCLUSION

Investigation into the causes of failure of solar street lights in Nigeria has been carried out. It has been found that one of the main reasons for these failures is lack of technical knowhow of the installers. In view of the huge amount involved in these installations, trained and qualified technicians should be made to handle such installations. Authorities concerned in the enforcement of standard should ensure that sub- standard component don't find their way into the market. Also, periodic maintenance should be included in the contract term during contract award. Finally, severe punishment should be meted out to those caught stealing solar street lights components so as to serve as deterrent to others.

REFERENCES

[1]. Oke A. O., Adigun A. A. & Fenwa O. D (2013) "Design and Construction of Solar Power-Based Lighting System" International Journal Of Engineering Sciences & Research Technology

[2]. Rita H. (2014) "A contribution to Solar Street Lighting in Developing Countries"

[3]. www.phocos.com

[4]. Peter A. (2014) "Feasibility of using solar PV and Light Emitting Diodes (LEDs) for Street-lights in Ghana: a case Study of Wenchi Municipality" A Thesis submitted to the Department of Mechanical Engineering, Kwame Nkrumah University of Science and Technology In partial Fulfillment of the requirements for the degree of Masters, College of |Engineering

[5]. Olayinka S. O., Muyiwa S. A., Olanrewaju. M. O. & Richard O. F. (2014) "Solar energy Applications and Development in Nigeria: Drivers and Barriers" Renewable and Sustainable Energy Reviews

[6]. Olatunde I. & Hartmut A. (2017) "Solar Photovoltaic Installation Supervision"

[7]. Antonio C.,J and Tom L.(2000) "Renewable Energy for Rural Schools" National Renewable Energy Laboratory".

[8]. Klaus J., Olindo I., Arno H.M., René A.C. & Miro Z.(2014) "Solar Energy Fundamentals, Technology and Systems" Delft University of Technology.

[9]. Norbert and Martin D. "Solar System Power of the Sun.

[10]. Parimita M., T. M., Eulalia J. G. and Yash K (2016) "Solar Radiation Fundamentals and PV System Components" Springer International Publishing Switzerland

[11]. Osaretin C.A. & Edeko F.O. (2015) " Design and Implementation of a Solar Charge Controller with Variable Output" Journal of Electrical and Electronic Engineering, Vol. 12, No. 2.

[12]. Iftikhar J. K., Yawar H. K., Salman R., Javed A. K. and Mian R. (2015) " Installation of Solar Power System used for Street Lights and Schools in Khyber Pakhtunkhwa, Pakistan" International Journal of Multidisciplinary Sciences and Engineering, vol. 6, no. 10.

[13]. http://eosweb.larc.nasa.gov/sse/

[14]. Qingguo X, Hongbo L, Guoqiang H. & Yefei D. (2016) "Study on Several Influencing Factors of Performance Evaluation Index of Photovoltaic System" Journal of Clean Energy Technologies, Vol. 4, No. 6.

Asaolu G.O, et. al. "Investigation Into The Causes Of Solar Street Lights Failure In Nigeria." *American Journal of Engineering Research (AJER)*, vol. 9(8), 2020, pp. 134-140.