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A STUDY ON OPTIMIZING THE PERFORMANCE PARAMETERS FOR SOLAR POWERED STREET LIGHTING SYSTEMS USING IMAGING-BASED DIAGNOSIS

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ABSTRACT

The study results are presented in this publication. System energy yield, capture loss, and the system performance ratio were used to analyses the technical performance of the systems, while a model created from the data collected during system maintenance and problem diagnostics was used to evaluate the systems' dependability. The Weibull distribution was utilized in the model to forecast the likelihood of system survival and total failure. The systems' performance ratios ranged from 70% to 89%, according to the performance evaluation conducted throughout the monitored period (February 2017 to January 2020), and their energy yields ranged from 2.87 h/day to 5.57 h/day. The reliability analysis's findings also indicated that the charge controller may overheat as stress concentration develops near the notch between the cable terminals, which will have an impact on other system components. This study's ramifications for the design and development of upcoming solar-powered street lighting systems are also examined.

Keywords: Solar Photovoltaic System, Performance Parameters, Smart Solar Grid, Reliability.

1. INTRODUCTION

The main energy source that affects the actual developments in the space and environmental framework is sun powered energy. How much sun powered energy that the earth gets every year is multiple times more prominent than how much petroleum products that have been found up until this point. Moreover, how much energy produced yearly by fossil, atomic, and hydroelectric plants is multiple times lower than that of sun based energy. Energy can appear in nature in various ways, including the sun and the breeze, similarly as it might in the inherent sciences in manners at any point like compound, potential, and active energy. Nonetheless, the creation of electrical energy normally includes the change of other energy sources, with petroleum derivatives ordinarily making up the principal phase of this cycle. Around 80% of the world's complete energy age comes from petroleum products. At the point when petroleum derivatives are singed, perilous gases such CO2, SO2, CO, NO2, and NO3 are delivered. Unforeseen environment shifts are welcomed on by the release of these gases. These variables have prompted an expansion in the interest for environmentally friendly power sources throughout the course of recent years. The level of advancement, the condition of the economy, and the creation and utilization of energy are firmly related in the present globe. Certainly, the expense of energy affects a country's economy. Following the modern unrest, populace and energy utilization are raising quickly all over the world. The world absolute requirement no matter what make the pressing progress to efficient power energy, with environmentally renewable energy sources (RESs) being the ideal sort. Wind and sun oriented energy are the two essential assets for extremely huge scope environmentally renewable energy (RE) collecting. Sun oriented assets can be collected more effectively and frequently than wind assets, despite the inconstancy and shortage of the breeze asset. Thus, sun based energy is an innovation that might be utilized for both little and enormous scope applications. As indicated by the supportable improvement reasoning, it is perfect energy. The quickest developing energy innovation overall is sun based energy, specifically. The two essential types of sun based energy are photovoltaic (PV) and concentrated solar power (CSP). No ifs, ands or buts, PV is more reasonable than CSP.

1.1. Solar Photovoltaic Systems

Approximately 21% of the energy that the sun radiates radially ever reaches the earth. Additionally, atmospheric interventions cause a significant percentage of the solar radiation to be attenuated before it reaches the earth's surface.

The sun-earth angle notion, as per which the sun powered energy got at the world's surface, vacillates on an hourly, everyday, or month to month premise, was the underpinning of before study. The course of the examination has been set

by effective examination of hourly variety made by the sun's movement from east west and furthermore by the presence of mists, day to day variety, and month to month (occasional) variety brought about by the place of the sun, which comes above two times every year in the tropical belt (Collares Pereira and Rabl 1979). Finding the force of sun oriented radiation and introducing the sun based PV module for more prominent result power both rely upon longitude and scope for finding a spot on the outer layer of the globe (Chang and Shen 2007). India has a huge sun oriented potential as a result of its area between the Jungle of Malignant growth and the Equator and its typical yearly temperature scope of 25°C to 27.5°C. Along the south-east shore of India, Tamil Nadu is perhaps of the sunniest state. The Tamil Nadu locale gets 5.4 to 6.2 kWh/m2/day of sunlight based radiation on normal every year (Singh et al 2005).

Most of unfortunate countries ordinarily have measurements on daylight term yet inappropriately recorded radiation information. The best wellspring of data for deciding an area's true capacity for sunlight based energy is sun oriented radiation information, which is likewise expected for the legitimate plan of a sun powered energy change framework. Much little examination has been finished on estimating sun radiation in unfortunate countries like India since they need specific meteorological stations. Sunlight based PV frameworks today merit thought for use in providing power. The PV framework is fit for providing power in various modes, remembering For Matrix/Lattice connected PV Frameworks and Off-Grid/Independent PV Frameworks. Off-Grid PV frameworks offer a substitute response in agricultural countries like India where customary power networks are unsound or nonexistent. The energy stockpiling highlight is the fundamental qualification between the Lattice connected and Off-grid frameworks. However, these systems all share the same functional goal of providing the client with electric power by converting the four sun energy. Due to the lack of a battery in their design, many researchers favor Grid connected PV power systems to Off-Grid connected PV power systems. Off-Grid PV systems may be a better option to create a flexible design in remote areas where grid connectivity is difficult and weak. The impact of solar evaluation, sizing strategy towards the components, and power delivered must be characterized, measured, and qualified in order to properly understand the behavior of Off-Grid PV systems. If it is not done correctly, the system might not be able to meet the demand.

1.2. Off-Grid Solar Photovoltaic Power System

Power from Off-Grid sources As the electricity grid frequently does not reach rural areas in many developing nations, solar photovoltaic power systems (OGSPVPS) are made easily accessible at remote locations, without grid connectivity. Because expanding the electricity system can be prohibitively expensive, developing countries are currently experiencing a boom in the process of electrifying rural areas using renewable energy sources (Byrne et al 1998). The two main options for electrification for Off-Grid sites in developing countries are the extension of the grid or the usage of diesel generators. Although costs vary depending on location, the quality of the PV resource, the price of the diesel fuel, the type of system, and other considerations, installing OGSPVPS can be more cost-effective than any of these options in many locations.

As OGSPVPS is more prevalent in developing countries and rural areas of India, it might be seen as a lifeline to civilization. OGSPVPS, which consists of photovoltaic modules, an energy storage system, a power electronic converter, and its matching controller, may use solar energy. Even though numerous researchers have worked on a variety of configurations, including Unregulated Off-Grid Systems with DC Loads, Regulated Off-Grid Systems with DC Loads, Regulated Off-Grid Systems with Battery and 5 DC Loads, Regulated Off-Grid Systems with Battery (Mohamed Dakkak et al. 2012), AC and DC Loads, and Regulated Off-Grid Hybrid Systems with Battery and DC Loa On the basis of the usage of various solar PV module, battery, controller, and power electronic converter types, a critical review of the contributions made by numerous researchers is identified.

A quick summary of the most recent contributions built on the components is provided in the sections that follow. Recent years have seen an increase in research opportunities for PV modules on two distinct technologies, thin film and wafer-based technologies. Under the same working conditions, the performance of modules from various technologies with the same power rating varies. Additionally, due to the affordability of silicon, aluminum, and silver, wafer-based PV modules are presently produced in greater quantities. Copper is

currently being used to replace silver in an effort to overcome the downsides. Comparatively speaking, there are no drawbacks with thin film modules. The research contributions show that understanding the precise performance of modules is regarded as a crucial element in the creation of an accurate photovoltaic system. Additionally, the manufacturer affects how a PV module performs in relation to temperature. Therefore, before optimizing the PV system design, the manufacturer's data sheet should be consulted (Ofualagba 2008).

Reviewing recent research on battery-based storage systems reveals that a number of factors, including battery capacity, voltage, depth of discharge (DOD), charging and discharging rate, battery life cycle, etc., affect the system's performance. Massive work on the most common batteries, such lead-acid and nickel-cadmium batteries resulted in their efficient use in PV systems. A typical lead acid battery is preferred for PV applications because it is straightforward, most durable, and inexpensive, has the lowest self-discharge, and can be charged by either constant current or constant voltage or a combination of the two. This is true even though recently many new storage systems 6 have emerged (Baldsing et al 1991). Additionally, the battery charge management system is seen to have become a well-known field of study recently. Many researchers have purposefully used the control of the power converter to regulate the power in the battery system.

In order to protect battery life and guarantee dependable performance, a design for the battery charge management system would undoubtedly incorporate a Charge Controller (CC). This device controls how a battery is charged and discharged. Recent studies on CC show the impact of the State Of Charge (SOC) and turn on its control to stop overcharging and deep draining in a battery system (Harrington and Dunlop 1992). Strenuous research-focused efforts were made to develop the current charge controllers, such as Shunt type CC, Series type CC, DC to DC converter type CC, and Maximum Power Point Tracking CC, with the development of OGSPVPS throughout the past ten years.

1.2.1. Power Electronic Converters

A thorough analysis of recent research shows that the PV system's power electronic converter layout has a significant impact on energy production and dependability (Pregelj et al 2002). A lot of research is being done to create effective inverters that can change the DC input voltage into an AC output voltage and produce waveforms including sine waves, modified square waves, multilayer waves, and square waves. Square and modified square wave are often categorized under low and medium power applications, while the others are categorized under high power applications, depending on the type of applications. For high power PV applications, multilevel inverters are a well-known topology that is frequently used. Additionally, matrix converters provide a number of benefits over conventional topologies, including sinusoidal input and output currents and the capacity to recycle energy back to the utility. As there are no big reactive components for energy storage, the converter's size can also be decreased.

Even though matrix converters are most frequently used for AC-AC conversion, recent advancements in DC-AC inversion and DC-DC chopper operations have opened up new possibilities for PV systems. Therefore, the choice of topology, application, and performance criteria should be seen as being more crucial before the design of OGSPVPS (Ertl et al 2002).

1.2.1.1. Multilevel inverters

Gigantic exploration zeroed in endeavors on multi-facet inverters were put forth trying to increment power by investigation of force semiconductor switches with many lower voltage DC sources, which were then used to do the power change by combining the important voltage waveform. Late ideas zeroed in on utilizing sustainable power voltage sources as opposed to batteries and capacitors.

Contrasted with a customary two-level converter that utilizes high exchanging recurrence Heartbeat Width Balance, a multi-facet converter has various benefits (PWM). The following are some appealing qualities of a multilayer converter.

- Enhancing stair waveform quality
- Worked at fundamental as well as high switching frequencies**.**

1.2.1.2. Matrix converters

By giving an "all silicon" answer for AC/AC transformation, the lattice converter gets rid of the need for the receptive energy stockpiling part seen in customary rectifier-inverter based frameworks. The best qualities that grid converters might give are:

- A simple, compact power circuit;

- The generation of load voltage with any amplitude; and • Frequency.
- Input and output currents that are sinusoidal
- Use of a power factor of one for all loads
- The power to regenerate.

The framework converters remember excellent highlights for expansion to the most regular AC to AC transformation, for example, the ability to adjust for various PWM procedures no matter what the kind of sources of info and results (AC or DC) and the quantity of information and result stages, by appropriately flipping the network switches. This technique enjoys the benefit of being versatile to a network converter. The different arrangements are separated by number of stages (the two information sources and results), kind of sources of info and results (DC or AC), and setup (Hosseini et al 2001) into the accompanying classes:

- Matrix converter for single-phase AC from DC
- Matrix converter for two-phase AC from DC
- A matrix converter for three-phase AC from DC.

The facts confirm that grid converters have a few disadvantages. Since there are no regular freewheeling courses, solid current substitution between switches in lattice converters is more difficult to create than in commonplace voltage source inverters. Also, it just so happens, the greatest result to include voltage proportion is not as much as solidarity.

2. HISTORICAL BACKGROUND

When working on solid state physics in the early 1880s, Edmond Becquerel unintentionally discovered the PV effect. The photovoltaic effect was first investigated two to three decades after it first gained popularity, and Adam and Day's study on the subject was first published in 1878. After that, in the late 1880s, Fxitz created the first thin solar cell, and significant research was done to forecast its effectiveness.

It's possible that the solar photovoltaic cell's poor efficiency was finally acknowledged. The construction of the silicon PV cell was successfully carried out by Russell Ohl in the 1940s, although it was incredibly inefficient. There was a resurgence of interest in solar photovoltaic materials in the early 1950s due to the rapid development of new types of materials and the ensuing desire to increase efficiency. The efficiency of manufactured PV cells had been improved in the late 1950s, and Chopin Fuller and Pearson reported 6% efficiency in 1958. Fortunately, the PV cell was employed in the spacecraft as a backup power source, extending its lifespan by nearly six years. Increased work has been developed with more concentration after silicon solar photovoltaic materials' efficiency rose to 14% in the late 1980s.

3. LITERATURE REVIEW

To plan PV frameworks, Mellit et al. (2010) portrayed a versatile - model utilizing all out sun oriented radiation information. To show and foresee the hourly worldwide, diffuse, and direct sun oriented radiation insights utilizing a Feed-Forward Brain Organization, the creators had proposed another versatile methodology (FFNN). The model for Jeddah, Saudi Arabia, area was created utilizing a data set of air temperature, relative dampness, immediate, diffuse, and worldwide flat brilliance. It was a while later guaranteed that the system furnishes 97% precision with a mean predisposition blunder of under 0.8.

An exhaustive specialized examination of planning and placing in the photovoltaic power framework was given by Khatib (2010). To assess the heaps and the sun oriented potential, an ideal methodology for planning and it was proposed to introduce the photovoltaic framework. To bring down framework blames and breaks and lift framework trustworthiness, suggestions were made for interfacing and introducing the PV framework. The results offered a financial appraisal of the PV framework utilizing the best procedure to exhibit the practicality of the framework.

A procedure for picking the best SASPVS size was depicted by Khatib in 2012. Five areas in Malaysia were analyzed, including Kuala Lumpur, Johor Bharu, Ipoh, Kuching, and Alor Setar. That's what the discoveries demonstrated, for obviously picked PV exhibit limit; the upsides of SOC and LOLP were good. Furthermore, a LOLP worth of still up in the air to cover 60% of the heap interest.

Jose et al. (2011) utilized a reenactment examination and MLS to show the flexibility of network geography. The creators utilized rectifier, inverter, buck converter, support converter, chopper, and cycloconverter to make sense of how a grid converter functions. Furthermore, the results show that the grid converter has a solidarity power factor, a low consonant contortion, and adaptable control.

Mohamed Dakkak and Adel Hasan (2012) looked at the OGSPVPS micro-controller-based charge

controllers. The prototype of an intelligent charge controller was created to extend battery life, and the findings confirmed that the design is flexible and has more monitoring and control features than the traditional logic and relay controller.

Huafen Hu (2012) created a risk-averse OGSPVPS for use in residential settings. To combine the system performance causes and predict all potential power availability outcomes of an off-grid dwelling design, a power reliability assessment method was created. Additionally, a stochastic model-based predictive controller was put into place to control how much energy the off-grid house would allocate to each of its 36 operating sub-functions. The proposed controller can aid the residents in reducing damages caused by power outages and improving the thermal comfort performance of the home, according to the results of the re-evaluation of the risk indices.

A high move forward DC converter utilizing a functioning exchanging LC-network was proposed by Gu et al. (2018). It tends to be applied to nearby planet groups since the front-end stage is answerable for delivering the vital DC transport voltage. This proposed converter presents an actively switched capacitor (ASC) organization, which depends on the transformer less DC converter with an active switched inductor (ASL) organization. Just a single capacitor and one diode are added to the converter in this proposition, yet the voltage gain is successfully expanded by joining the ASL and ASC organizations. The additional diode and capacitor are exposed to negligible voltage strains thanks to the converter's clear structure.

A high move forward converter was made by Andrade et al. in 2019. In the recommended plan, the customary lift converter is joined with a connected inductor, a few exchanged capacitor draws near, and another crossover high voltage gain dc converter. The proposed converter gives a high voltage gain and high productivity with a solitary switch and without the requirement for more noteworthy obligation cycle values, as well as decreasing the voltage and current tensions on the parts.

3.1. Research Gap

Study	Approach	Research gap
Md.Tanvir Arafat Arafat Khan, S.M. Shahrear Tanzil ,Rifat Rehman ,S M Shafful Alam " Design and construction of an Automatic Solar tracking System", ICECE 2010 6TH International Conference on Electrical and Computer Engineering18-20 December 2010 Dhaka, Bangladesh	P&O MPPT technique	Miscalculating MPP in the midst of abruptly altering weather conditions.
D. Sera, T. Kerekes, R. Teodorescu, F. Blaabjerg, "Improved MPPT Algorithms for Rapidly Changing Environmental Conditions," in Proc. 12th International Conference on Power Electronics and Motion Control, 2006, pp. 1614-1619.	Incremental conductance MPPT method	MPP is easily lost if the irradiation changes quickly. the voltage and current oscillations around the MPP in the steady state

4. METHODOLOGY

4.1. Installation and Site Description

The review site, African College of Science and Innovation, is situated in Abuja, north-focal Nigeria, at scope 9°03'36"N, longitude 7°29'24"E and a height of around 520 m. 35 sunlight based fueled Drove road lighting units were introduced in 2012 at the area. They were set up as a part of the Nelson Mandela Foundation and the Division of Materials Science and Designing at AUST's joint sun oriented project. The frameworks were at first set up to increment security during a power outage and to save energy. They were put along pathways and in other key areas around the property. In any case, it has long filled in as a stage for study and examination concerning sun based energy courses presented by the division of Materials and Designing. Moreover, to work on the exhibition of the boards, the directions of the boards are put toward the south at a slant point of 30°, considering that board direction is one of the key components that decides how much light can be reaped from the sun every day.

4.2. Performance evaluations

For three (3) years, from February 2012 to January 2015, the frameworks were noticed. This prompted the typical everyday/month to month sun oriented light being estimated with a pyrometer (Apogee Instrument USA, MP-100 vital sensor with handheld meter) and contrasted and results from the Nigerian Meteorological Organization as one of the devices in examining the specialized presentation of the PV frameworks (NIMET). The DC voltages and DC power is several different factors that were noticed over the course of this time.

4.2.1. System energy yield

The ratio of the system's DC energy output (kWh/m^2) to installed capacity to PV solar panel area (kWp/m^2) is known as the system energy yield, or Y_A (h/day), and is calculated as follows:

$$Y_A = \frac{E_{DC}}{P_0}$$

4.2.2. Reference yield

The proportion of the complete every day in-plane radiation on the PV sunlight based charger to the reference in-plane radiation is known as the reference yield, YR (h/day). Therefore,

$$Y_R = \frac{H}{G}$$

Where G is the reference radiation, assumed to be 1 kWh/ m^2, and H is the total daily in-plane radiation on the solar panel (kWh/m^2).

4.2.3. Capture loss

Loss of panel capture between the reference yield and the system energy yield, there is a discrepancy called LC.

$$\mathbf{LC = YR - YA}$$

Since YR is the reference yield and YA is the system energy yield, LC = YR YA (3).

4.2.4. Performance Ratio

The performance ratio (PR), which is the ratio of system energy yield to reference yield, is typically used to assess the quality of solar PV systems (street lighting systems). This is derived using the expression shown below:

$$P_R = \frac{Y_R}{Y_A}$$

4.3. Reliability model

After 35 sun based road lighting frameworks at AUST had their support work and blames distinguished, 24 frameworks (or 68.57%) were found to be ready to go, 10 frameworks (or 28.57%) were flawed because of a few harmed parts, and 1 framework (or 2.86%) had been totally obliterated by a thunder strike (see Table 1). The breaking down frameworks was recognized to research possible reasons for their disappointments. Various specialized assessments of the framework's parts, including the useful testing of the sun powered chargers, charge regulators, batteries, associations, and so on, were expected for the issue determination. Notwithstanding, the shortcoming determination recognized various significant issues, which are recorded in Table 1 underneath.

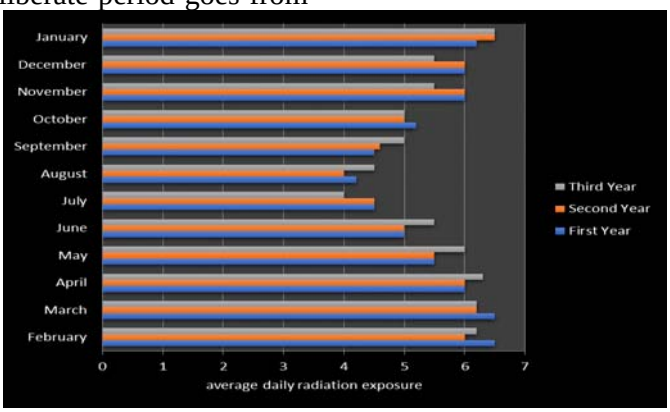
Table 1: Damaged Solar PV System Components

Components	Controllers	Light emitting Diodes	Batteries	Cables	Panels
Number of Systems	12	2	7	12	2

5. RESULT AND DISCUSSION

5.1. Abuja's typical daily irradiance

For the review site from February 2017 to January 2020, the upsides of the month to month normal everyday light are displayed in Fig. 1. 5.49 kWh/m2 is the day to day typical irradiance for the time span under perception. Also, as displayed in Fig. 1, the month to month normal everyday illumination during the deliberate period goes from 4.10 to 6.51 kWh/m2. The month to month normal day to day illumination diminished essentially among June and September because of the wet season, which is additionally gathered from Fig. 1. The twice of most elevated top light occurred in February and Walk, though the two times of least pinnacle illumination occurred in July and August, separately.



5.2. System energy yield and capture loss

When the data from the three years of research are compared, it becomes clear that for all three years in a row, February was the month with the highest average energy yield. This can be linked to February's sun irradiation, which had the greatest value over the course of the three-year study. The principal year of the review (February 2017 to January 2020) had a typical day to day energy yield of 4.52 hours, which was trailed constantly year (4.48 hours/day). The third year of the review saw the least yearly arrived at the midpoint of everyday energy yield, 4.44 h/day.

5.3. System performance ratio

The framework's performance ratio (PR), which is resolved utilizing Condition, depicts the presentation of the sun based road lighting framework. The adequacy of the sun based road lighting frameworks' associations with the sun oriented radiation present at the review area is checked by the exhibition proportion. The framework execution proportions for the first, second, and third long periods of exploration, individually, range from 71% to 87%, 70% to 87%, and 70% to 89%. In any case, after the review period, every one of the months has a PR esteem more noteworthy than 83%, except for July, August, and September. Because of the absence of sun illumination at the exploration site because of the wet season, the sun oriented road lighting frameworks failed to meet expectations during this three-month time span.

5.4. Analysis of Reliability

Inverter disappointments are basically to fault for PV framework disappointments. Nonetheless, a few episodes might be connected to different elements, including human mistake and catastrophic events, batteries, and charge regulators, as on account of sunlight based PV road lighting frameworks. As needs be, it very well may be gathered from Table 1's dependability information that 2.86 percent of LEDs, 2.86 percent of sunlight powered chargers, 14.29% of batteries, and 28.6 percent of charge regulators neglected to arrive at their base anticipated life expectancies (Drove: 6-8 years, sunlight powered charger: 20-25 years, battery: 4-6 years, and charge regulator: 5-15 years, separately). As per the review displayed over, a huge part of the charge regulators neglected to arrive at the necessary least life expectancy.

Fig. 1 presents an outline of the dependability examination of sun oriented PV road lighting frameworks. The dependability examination shows that the charge regulators of the imperfect PV frameworks were harmed because of the development of stress nearby between the charge regulator's link terminals. This exhibits that the charge regulator will overheat when the pressure fixation factor close to the score between the link terminals in the gadget develops, which could cause framework harm.

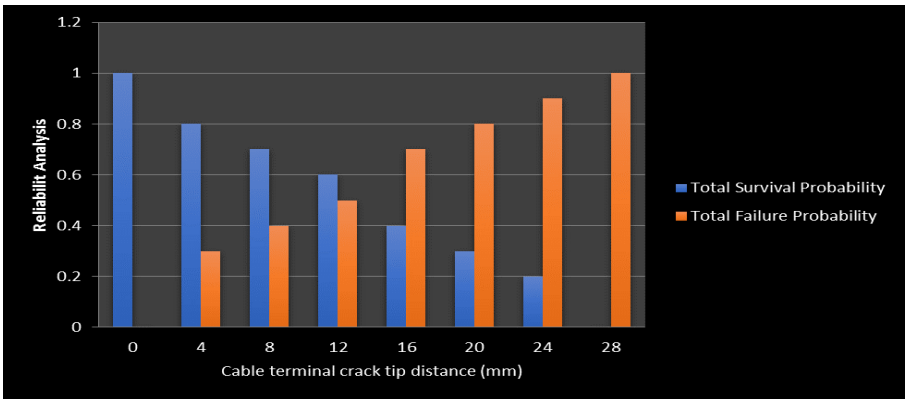


Figure 1: Analysis of Solar PV Street Lighting Systems' Reliability

6. CONCLUSION

This study explores the adequacy and steadfastness of sunlight based fueled road lighting frameworks. The energy yield, catch misfortunes, and execution proportion are thought about as the benchmark for the exhibition assessment as per the standards laid out by the IEA and IEC. To start with, that's what the discoveries show, for the observed period, the sunlight based controlled road lighting frameworks' exhibition proportions went from 70% to 89% and their energy yields from 2.87 to 5.57 hours of the day. The pinnacle normal energy yield and execution proportion were at their most elevated in

February 2017. That very month likewise had the most reduced catch misfortune during the noticed time period. Moreover, the dependability examination's discoveries exhibited that the charge regulators of the imperfect PV frameworks were harmed because of the development of stress nearby between the charge regulator's link terminals, which thusly affected certain other PV framework parts (like link, battery, and so on.). Point of fact, utilizing a top notch charge regulator can empower observing and quick investigating of the frameworks as well as shield and extend the battery duration of the PV framework.

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