Design, Development & Performance Evaluation of round lead acid battery for solar street light application

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ABSTRACT
This study reveals the Design, Fabrication and Performance Evaluation for the 12 V /15 AH lead acid battery for the street light application using FRP container having diameter 6 inches 12 inches height
This paper reveals the new innovative design, development of the lead acid battery for solar street light application. The battery is designed with FRP container having electrolyte (sulphuric acid + pure water) of size 298.8 mm I.D. and 304.8 mm O.D. The battery is tested on dichoric lamp (12V/50W) & LED lamp (12V/20W) is tested as per testing standards. The maximum back up is obtained from these two lamps. This new change in geometry of lead acid battery is found more efficient and this work will help the designers and manufacturers in this field to establish refined products and better services vis-a-vis users in long term when compared with other type rectangular solar lead acid battery. The paper concludes achievement of energy storage device using geometry change technology with low cost, light in weight for solar street light application.

I. INTRODUCTION
The solar power is being used for street lighting around the world & the trend is increasing. The long term power saving, conservation of precious natural resources and elimination of the need for generating additional power are leading to the fast adoption of solar street lighting systems. The most systems use a deep cycle battery to store excess power for use at night and on cloudy days. They also present some safety risks when it is fixed on to pole and require special handling, depending on the type of battery used. Batteries serve as a storage device for electrical energy. Although the general idea is simple, batteries must be carefully selected and maintained to have a reliable power system. These batteries are fixed in a box but it has chance of theft. Risk of theft is higher as equipment costs are comparatively higher. The access for maintenance is also more difficult & hence neglected leading to failure the system.

There is need to develop low cost solar energy storage device for street light applications. To fulfil the outline of the present paper, a literature review followed with scope of paper is given as follows.

The lead-acid battery has become so dependable in its usual applications of automobile starting, emergency lighting, and telecommunications, that the belief has arisen erroneously that no further investigation of this battery is necessary or desirable. Considering the long time that this battery has existed, there has been relatively little effort to understand the complex chemistry and electrochemistry upon which the successful operation of the battery system is based. This lack of research arises partly from the fact that this is a highly competitive and cost conscious industry which does not encourage research expenditure, and partly from the fact that it has been possible in the past to produce a product, without extensive research, that has been adequate for most prior applications.[1]

Solar street lights are raised light sources which are powered by photovoltaic panels generally mounted on the lighting structure. The photovoltaic panels charge a rechargeable battery, which powers a fluorescent or LED lamp during the night. Initial investment is higher compared to conventional street lights. Risk of theft is higher as equipment costs are comparatively higher [2]
The Intermittency Challenge and the approaching need for massive storage of rapidly dispatchable energy has led the concept of the lead acid battery, a unified facility that holds the aggregated outputs from an array of intrinsically episodic renewable sources, releasing energy as demand requires. In this contribution, the original demonstration of lead-acid batteries are inappropriate is first reviewed and then extended to show that no commercially available battery technology is at present appropriate.[3]

Batteries used in photovoltaic applications are required to have particular properties in order to minimize the system cost, in addition to meeting stringent reliability requirements associated with PV system installations. The battery sizing, installation, operation and maintenance, thus, are fundamentally different from those used in several other energy storage applications[4]

A photovoltaic system converts sunlight into electricity. The elements of such a system are briefly described. Performance characteristics of these systems under local atmospheric conditions are presented. Urban applications of photovoltaic solar cells and cost goals are indicated. The costs, a rapid growth in sales of lead-acid batteries , the introduction of improved corrosion-resistant alloys, a better understanding of battery electrochemistry & the associated mechanisms that affect battery life and performance, as well as the development of low-resistance and more durable separators. As a result, the performance of the battery has almost doubled while the weight of it has been reduced by more than 30% [5]

The principles of the operation and manufacture of different designs of lead–acid battery are described, together with a description of potential failure mechanisms and the methods by which they may be overcome. The challenges and prospects for future lead–acid technologies to meet the requirements of emerging new applications are reviewed. [6]

This project work therefore has decided to do the R&D on changing shape of lead acid batteries which can be fit inside the pole to avoid existing disadvantages of lead acid batteries. The performance of new batteries needs to be checked before its recommendations.

As we know rectangular lead acid battery has been used for SLI application for many years. But now-days development in this technology has been made and used in various operations. Thus there is a need of exact technology to be developed with quantitative parameters for low cost & light weight in application with proper design and development.

II. METHODOLOGY FOR PROJECT DEVELOPMENT:

When selecting lead-acid batteries for the street light application, it is important to match the battery to the application. More than anything, this means selecting a battery that has enough capacity for the application. But there are different types of batteries in market such as starter battery, deep cycle battery and marine battery. The battery selection decision for the street light application should include the consideration of several important factors such as those presented here. The selection of the appropriate battery that will provide the economical, low cost profile, reliability, operating characteristics, battery life, and performance that are critical to a successful application of the battery system.

Therefore there is need for right technology to be developed which is solved by geometry change of lead acid battery for street light applications to avoid theft & maintenance .Thus exact parameters are required to be operated for required application and requirement of proper data for its design and development. By keeping all facts in view, the study has been initiated to design and develop an energy storage device with its installation followed by its Testing and Performance evaluation for street light application.
2.1 Case study under reference for design purpose & evaluation of parameters

This project work is aimed to establish parametric study of existing lead acid battery used for street lighting purpose its performance evaluation.

This work will help the designers and manufacturers in this field to establish refined products and better services vis-a-vis users in long term. The utility of the solar product will also be proved if the existing disadvantages are removed.

The project development methodology is designed to develop the lead acid battery suitable for solar street lighting system and to refine the product for better utility. The research has to be concentrated in changing the geometry of the battery to fit in to the pole without affecting the performance of the battery or to improve the performance in long term.

2.2 Design Methodology

Sizing a stationary battery is important to ensure that the loads being supplied or the power system being supported are adequately catered for by the battery for the period of time (i.e. autonomy) for which it is designed. Improper battery sizing can lead to poor autonomy times, permanent damage to battery cells from over-discharge, low load voltages, etc. Following design parameters are to be fixed:

- Shape of the battery
- Battery loads that need to be supported
- Nominal battery voltage
- Autonomy time(s)

It requires further consideration of:

1) The battery type and determine the characteristics of the cell
2) Construct a load profile and calculate the design energy (VAh)
3) The loads that the battery needs to support
4) The number of battery cells to be connected in series
5) Ampere-hour (Ah) capacity of the battery

Step 1: Collect the battery loads

The first step is to determine the loads i.e. 12 watts LED fittings fixtures.

Step 2: Construct the Load Profile

It depends upon the Load Profile Calculation i.e. description of Load, power factor, for the design energy, E_d in VAh. By considering 12 Watt LED

We know that

\[ P = VI \cos \phi \]

\[ \cos \phi = 0.85 \]

\[ VI = \frac{P}{\cos \phi} = \frac{12}{0.85} = 14.11 \text{ V-Amperes} \]

\[ E_d = 141.1 \text{ VAh} \]

Step 3: Select Battery Type

The next step is to select the battery type (e.g. sealed lead-acid). The selection process is not covered in detail here, but the following factors should be taken into account Physical characteristics, e.g. dimensions, weight, container material, inter cell connections, terminals

Next, find the characteristics of the battery cells, typically from supplier data sheets. The characteristics that should be collected include:

- Battery cell capacities (Ah)
- Cell temperature
- Electrolyte density at full charge (for lead-acid batteries)
- Cell float voltage
- Cell end-of-discharge voltage (EODV).

Step 4: Number of Cells in Series

The number of battery cells required to be connected in series must fall between the two following limits:

\[ N = \frac{V_{dc} \times (1 - V_{lmax})}{V_{eod}} \]

Where \( N \) is the number of battery cells

\( V_{dc} \) is the nominal battery voltage (Vdc)

\( V_{lmax} \) is the maximum load voltage tolerance (\%) = 10%

\( V_{eod} \) is the cell end of discharge voltage (Vdc) = 1.8 Volt

\[ 12 (1 - 0.1) \]

\[ N = \frac{12}{1.8} = 6 \text{ Cell} \]

Step 5: Determine Battery Capacity
The battery capacity required to accommodate the design load over the specified autonomy time can be calculated as follows:

\[ C = \frac{E_d \times K_a \times K_t \times K_c}{V_{dc} \times K_{DOD}} \]

Where \( C \) is the battery capacity (Ah)
\( E_d \) is the design energy over the autonomy time (VAh) = 141.1 VA-Hrs
\( V_{dc} \) is the nominal battery voltage (Vdc) = 12Volt
\( K_a \) is a battery ageing factor (%) = 25 % = 1.25
\( K_t \) is a temperature correction factor (%) = at 30 deg Celsius =0.956
\( K_c \) is a capacity rating factor (%) = 10 % of the capacity = 1.10
\( K_{DOD} \) is the maximum depth of discharge (%) = 0.80

Put all this values in above equation
We get,
\[ C = \frac{141.1 \times (1.25 \times 1.25 \times 0.956 \times 1.10)}{12 \times 0.80} \]
\[ C = 19.32 \text{ Amp-Hour (AH)} \approx 20 \text{ AH} \]

2.3 Testing & Analysis

Testing is necessary to see whether user defined specifications have been incorporated in the design of battery. Regular testing ensures consistency of quality and reliability of the product with the help of testing equipment & its set up of charging & discharging battery

Batteries are tested for discharges at maximum currents as the capacity of battery, Experimental set up for lead acid battery

Circuit diagram of Charging the battery with the help of charger
Discharging the battery with the help of load given by a) Dichoric lamp b) LED lamp

III. RESULTS & DISCUSSION

1) Time (Hours) verses battery current (A) and battery voltage (V)

Fig: 1 Constant Current Charging method

This graph 7.1 shows when 12 Volt battery charges at constant 1.5 Ampere current with respect to time, the battery voltage is increased. This charging method is very effective for recovering the capacity of battery. At full charged condition battery voltage around of 15.32V. The result matches standard same capacity of rectangular battery charging & discharging. The rate of increase of battery terminals voltage is initially more and tries to be stabilize after b hours of battery charging.

2) Voltage (V) verses specific gravity

Fig: 2 Charging Characteristics Curve With Voltage

This graph shows when 12 Volt battery charges at constant 1.5 Ampere current with respect to charging time, the battery voltage is increased. When charging current flows through the cell voltage as well as battery voltage is increased with specific gravity of electrolyte. When battery is fully charged, the specific gravity of electrolyte is 1.265
3) Hours Vs Battery charging & discharging voltage (Comparison of voltage of 50 W & 24 W)

This graph is comparison between dichoric lamp of 50 W and LED lamp of 24 W. From above it is said the maximum current (3.35 ampere) is drain in 2.50 hours from the 50W lamp than the LED lamp. The fall of rate of current drain is increased & finally battery is discharged in 3.75 hours. But in case LED of fall of rate of current is slower as compared to 50W & it is discharged in 16 hours, there is continuous drop in voltage after each hour & finally it reaches with 10.86V. From above two lamp it is conclude that LED is better efficient than the dichoric lamp.

4) Hours Vs Battery Current (Comparison of battery discharging current of 50W dichoric lamp with 24 W LED lamp)

This graph is comparison between dichoric lamp of 50 W and LED lamp of 24 W. From above it is said the maximum current (3.35 ampere) is drain in 2.50 hours from the 50W lamp than the LED lamp. The fall of rate of current drain is increased & finally battery is discharged in 3.75 hours. But in case LED of fall of rate of current is slower as compared to 50W & it is discharged in 16 hours, there is continuous drop in voltage after each hour & finally it reaches with 10.86V. From above two lamp it is conclude that LED is better efficient than the dichoric lamp.

IV CONCLUSION

It is found that usage of solar street light is increasing day by day. It has night duty hour’s applications & hence need of electrical storage which is made by existing rectangular lead acid battery. However rectangular lead acid battery has disadvantages of maintenance & risk of thefts which has resulting its limited usage of solar street light system.

This project has delts with alternative tool of disadvantage faces as on today & creative thought has been given for design, development & performance evaluation solar round lead acid battery for street light application. Commonly 12 W LED fitting fixture is use for street light at 4m height of pole & for one day autonomy 12 Volts 15 AH rectangular battery is used. A replacement has been thought for design, & development of 12V 15 AH round lead acid battery which can be fit inside pole at a suitable height which can be avoid existence disadvantages of solar street light system. It is strongly conclude that round cylindrical vertical battery behaves better than existing standards branded rectangular battery & removes existing disadvantage of maintenance & the theft & hence it is strongly recommended such battery can be replaced in existing solar street light system as per capacity required.

REFERENCES


