

Electrical Output in Photogalvanic Cell for Conversion of Energy and Storage by Using Bismarck Brown with Different Reductant

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Abstract:- Photogalvanic (PG) cell are dye-sensitized solution-based solar energy converters and storage devices. The photogalvanic of Bismarck Brown (BB) as a dye sensitizer with different reductant such as Ascorbic Acid (AA), EDTA, and Glucose (Glu.) have been investigated in order to obtain new insights into how to make PG cells that become relatively cheaper, cleaner, and environmentally acceptable. In this study, three systems BB - AA, BB - EDTA, and BB - Glu were examined utilizing PG cells. The Photocurrent generated by these systems was 915 mV, 810 mV and 720 mV and Photopotential generated by three systems was 155 μ A, 135 μ A and 120 μ A, respectively. The factor of fill for BB - AA, BB - EDTA, and BB - Glu systems were 0.54 %, 0.48 % and 0.40 %, Efficiencies of conversion for BB - AA BB - EDTA, and BB - Glu systems were 0.899 %, 0.614 % and 0.405 % and Capacities of storage for BB - AA, BB - EDTA, and BB - Glu systems were 40 min., 34 min. and 31 min., respectively. The effects of various factors on the electrical outputs of the cell have been observed, and a mechanism for the generation of photocurrent in PG cells has also been suggested.

Keywords:- Bismarck Brown, Glucose, EDTA, Ascorbic Acid, Conversion Efficiencies, Fill Factor.

I. INTRODUCTION

The development of technology for producing renewable energy is in high demand in today's globe. We are up against a challenge to supply the growing global demand for electricity without harming the environment. The amount of sun light that touches the world in an hour is greater than the total power that the earth expends in a year. The greatest tool for converting solar power into electrical power is a solar focused cell. The goal of research on sunshine-based cells is to improve the efficiency of sunlight conversion while also addressing the need for a viable power source.

Becquerel [1839] found that a power and electric current was formed when a silver chloride cathode was immersed in an electrolyte and connected to a counter terminal that was lit up with sunshine. It was the beginning of the forefront period of photoelectrochemical cells in terms of

photoelectrochemical effect, and it is known as the Becquerel effect, which is the origin of the photovoltaic wonder. Fox, Kabir-Ud-Din and Singletary [1979] observed five photo processes entail basic carbanion, which are ring opening, isomerization anionradical creation, reductive alkylation, and electron transfer with anodic current production, indicating that carnation undergoes photoinduced chemical reactions.

Aliwi, Naman and Al-Dhstani [1986] reported that in a photogalvanic cell with platinum electrode, photogalvanic effect in a photo redox couple constituted of Vanadium(III)bis(2,2'-bipyridyl)Chloride and Fe(III) was investigated in aqueous solution. They found that incident light intensity has a direct relationship with cell photocurrent and photopotential, and that photo current and photopotential are proportional to incident light intensity. Baranham, Mazzer and Clive [2006] observed the It will take fresh initiatives to increase the efficiency with which incoming photons are harvested by using Safranin-o used as a photosensitizer. The photopotential and photocurrent generated were respectively 790.0 mV and 185.0 A. The observed conversion efficiency was 0.1469 percent, the fill factor was 0.08, and the cell's highest power was 146.15 W, whereas the photogalvanic cell's power at power point was 15.28 W.

Yadav, Singh and Yadav [2009,2010] were investigated the photogalvanic effect of photosensitizer – reductant by using the Victoria Blue and Ascorbic Acid system and Thionine- EDTA- CTAB for solar energy conversion and storage. This cell produced a photopotential of 662mV and a photocurrent of 150A, respectively. The cell's maximum power output was 53.5 watts. The conversion efficiency was found to be 0.5144 percent, with a fill factor of 0.50. Gangotri, Regar , Lal , Genwa , Kalla and Meena [1997,2011] studied a comparison of photogalvanic cell performance with several photosensitizers for solar energy conversion and storage of D-Xylose-NaLS systems using several photosensitizers such as Methyl Orange, Rose Bengal, Toluidine Blue, and Brilliant Cresyl Blue, as well as D-Xylose as a reductant and Sodium Lauryl Sulphate (NaLS) as a surfactant.

Yadav [2017] reported the Comparative Study of photogalvanic effect by using of Rose flower Extract as photosensitizer with Mannitol and NTA as reductant for solar energy conversion and storage performance. Yadav [2018] explained that in this study, the photogalvanic effect was investigated. The natural dye was Rose Extract, while the reductant was Nitrilotriacetic acid. The voltage and current generated by this cell were 872 mV and 176 A, respectively. The conversion efficiency was 0.79 percent and the observed power at power point was 82.18 W. At the cell's power point, the fill factor 0.4678 was determined experimentally. The PG cell can be used in dark for 42 min. and charging time was 200 min.

Chadra M, Shree T [2019] Reported renewables have the potential to play a significant role in rural electrification if we properly equip and utilise these technologies and opportunities. Energy conservation is one of the most important issues. As a result, new technology and energy efficiency are critical to solving our energy conservation and global warming challenges Photogalvanic effect has observed in a system which contain a dye Victoria Blue act as photosensitizer and a reducing agent Ascorbic acid.

Koli, Dayma, Pareek and Jonwal [2020] explained that Congo red is being used in photogalvanic cells to improve simultaneous solar energy conversion and storage. Congo red dye has been observed to have lower aggregation at high pH, which makes it suitable for photogalvanic applications. Koli P, Pareek, Dayma and Jonwal [2021] observed that Photosensitizer Indigo Carmine dye-surfactant Sodium Lauryl Sulphate-reductant Formic acid-NaOH alkaline medium photogalvanic cells have shown encouraging and very impressive improvements in solar energy conversion and storage.

Chandra [2021] Studied on four systems namely Rh B – EDTA - Tween80, MB – DTA -NaLS, Rh 6G – EDTA - CTAB & Safranine - EDTA – ALS in PG cells and In the year 2050, it was also reported that in developing regions of the world, energy consumption is expected to expand fast, with the fundamental energy requirement not being met satisfactorily. Koli [2021] observed the Sudan-I dye (photosensitizer)-Fructose (reductant)-Sodium Lauryl Sulfate (surfactant) photogalvanics have been studied in alkaline medium at low and artificial sun intensity with the goal of finding a relatively better combination of chemicals like photosensitizer, reductant, and surfactant for further enhancing the efficiency of these cells.

II. MATERIALS AND METHODS

Bismarck Brown, which was utilized as a photosensitizer, is a metachromatic dye with the chemical formula $(H_2N)_2C_6H_3N_2]_2C_6H_4$ with a molecular mass is 419.31. Three Reductant was used (1) Ascorbic Acid has the chemical formula $C_6H_8O_6$ with a molecular mass is 176.12, (2) EDTA has the chemical formula $C_{10}H_{16}N_2O_8$ with a molecular mass is 292.2438 and (3) Glucose has the chemical formula $C_6H_{12}O_6$ with a molecular mass is 180.156. Triple distilled water was used for the preparation of these solutions. These

solutions were stored in amber-colored bottles to keep them out of the sun. As a photogalvanic cell, an H-shaped cell was utilised with a known number of photosensitizers, sodium hydroxide, reductant, distilled water and the total volume was adjusted to 25 ml. The H type cell's one arm was submerged in a saturated calomel electrode while the other arm was immersed in a platinum electrode. Alkali solution was employed to keep the pH of the fluid in the photogalvanic cell stable when needed. Standard oxalic acid used to standardise the alkali solution, and a digital pH metre (Systronics model 802) was utilised to measure the pH though solution. At a predetermined time period, an electronic pH metre was utilised to monitor the system's fluctuation in potential difference. To achieve a steady potential, the device was first maintained in the dark. This stable potential became the dark potential when the platinum electrode was lit via the window generated in the H type cell's arm. A 200W tungsten filament lamp was used as a light source. After illuminating the system for a length of time, a steady potential is obtained. The photopotential is calculated by subtracting the dark potential from the stable potential obtained after lighting (mV). The current generated in the photochemical system was measured using a micro-ammeter (New Tech, India).

After achieving a stable photopotential under illumination, the current was measured. In the same system, changes in current with respect to time, maximum photocurrent, and current at equilibrium were observed. The system's current-voltage (i-V) experiments were conducted utilising an inside the circuit an external load (log 470K) determine the power point, which is defined as the point at which the multiplication of potential and current is greatest. The cell's performance was measured at its maximum power. It was calculated using the pace at which the cell's power dropped when the illumination was turned off. To achieve current and potential values that were equal to those at power point, an external load was used. The time it took to reach half of the power point value was then recorded. This is referred to as $t_{1/2}$, and it is a measure of a cell's ability to function in the dark. The Factor of Filling of the cell was determined using the formulae where i_{pp} and V_{pp} denote photocurrent and photopotential at power point, respectively, and V_{oc} and i_{sc} denote open and short circuit photopotential and photocurrent, respectively. Conversion Efficiency in Cells was determined using current and potential values at the power point, as well as light intensity. The formula was as follows:

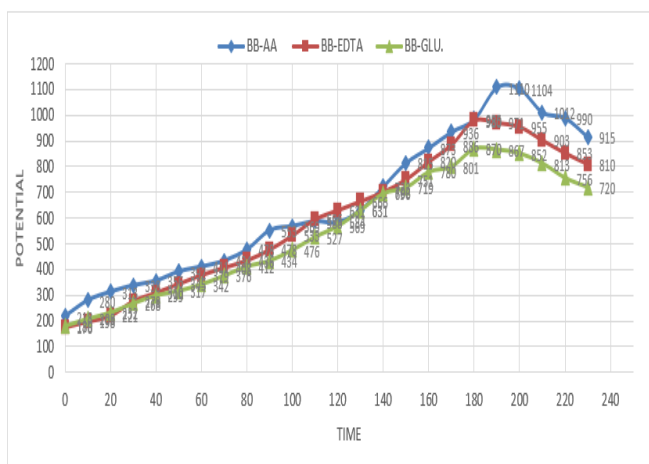
$$\text{Conversion Efficiency} = \frac{V_{pp} \times i_{pp}}{10.4mWcm^{-2}} \times 100 \%$$

Photopotential and photocurrent at point of power are denoted by V_{pp} and i_{pp} .

III. DISCUSSIONS AND FINDINGS

A. Potential Variation during Time

After the photogalvanic cell has been put in the dark, the electrode of platinum was affected by light until it attained a steady potential. It had been discovered that when illumination increased, potential altered and eventually reached its maximum value after a period of time. When the light source was removed, the cell's potential was reduced, and after some time, a steady potential was achieved. After obtaining a stable potential by keeping the system dark, the potential increased with lighting and reached its maximum value, known as open circuit voltage (V_{oc}), before the light source was removed and the cell's potential was lowered. Graph- 1 shows across all three systems, the fluctuation of potential with time in pg cell. The potential was found to increase when the source of light was illuminated; the direction of possible change was discovered to be reversed when the source of light was removed. In all three systems, distinct time periods were noted for obtaining the stable dark potential as well as achieving a stable potential after lighting.



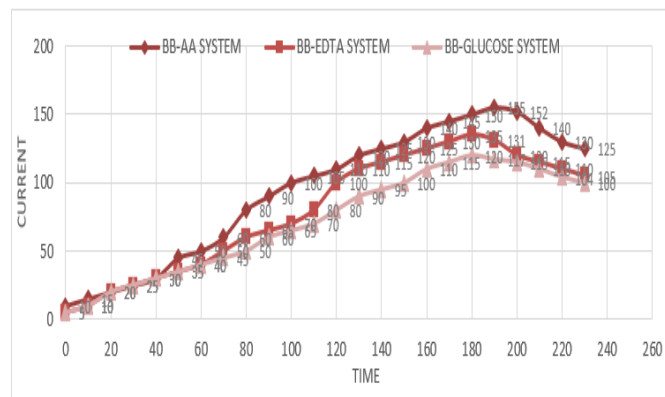
Graph1. Indicates how potential changes over time.

The BB-AA System had the highest open circuit voltage, whereas the BB-Glu. System had the lowest. The BB-AA System had the highest voltage at power point, while the BB-Glu. System had the lowest. In the BB-AA System, BB-EDTA System, BB-Glu. System, the rate of change in potential on illumination was 6.02, 5.28, and 4.48 mV min⁻¹, respectively. In the BB-AA System, BB-EDTA System, BB-Glu. System, the rate of change in potential after removing the source of light was 2.23, 2.11, and 1.86 min⁻¹, respectively. V_{oc} and V for BB-AA system =1110.0 mV and 915.0 mV, V_{oc} and V for BB-EDTA system =980.0 mV and 810.0 mV and V_{oc} and V for BB-Glu. system=870.0 mV and 720.0 mV. As a result of the following the photogalvanic cell is most efficient with the BB-AA System and least efficient with the BB-Glu. System, according to the overall results.

B. Current Variation during Time

The current in all three systems rapidly increases after a few minutes of illumination, reaching maximum value (I_{max}) of 198.0, 180.0, and 170.0 A in the BB-AA System, BB-EDTA System, and BB-Glu. System, respectively, and rates of the first generation of current are in the order of 19.2, 15.3,

and 13.4, A min⁻¹ in BB-Glu. System, respectively. In the BB-AA System, the short circuit current (i_{sc}) (i_{eq}) was measured at 155.0 A, 135.0 A in the BB-EDTA System, and 120.0 A in the BB-Glu. System. The outcomes are shown in Graph- 2.

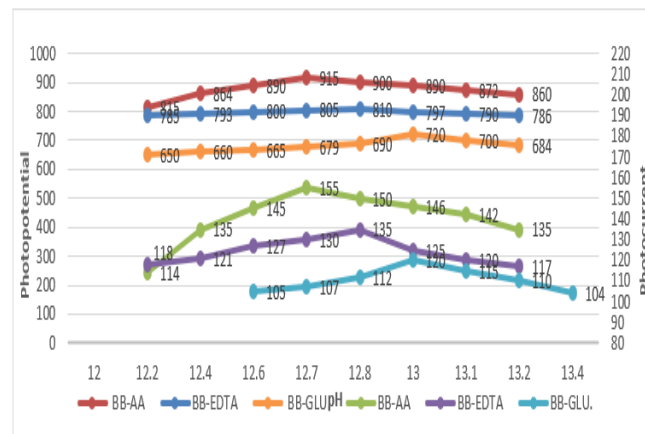


Graph 2. Displays how current changes over time.

In the following the photogalvanic cell is most efficient with the BB-AA System and least efficient with the BB-Glu. System, according to the overall results.

C. Variation in pH's Effect

The impact of a pH shift on photopotential in the three systems is presented in Graph- 3. All three systems with photosensitizers (dye) were found to work efficiently in the strong alkaline range. pH=12.7 to 13.0 was the working range for this study. The photopotential of the system was observed to grow as the pH was raised, reaching a maximum value for a certain pH, and then falling as the pH was raised further.



Graph 3. Shows the Effect of Variation of pH

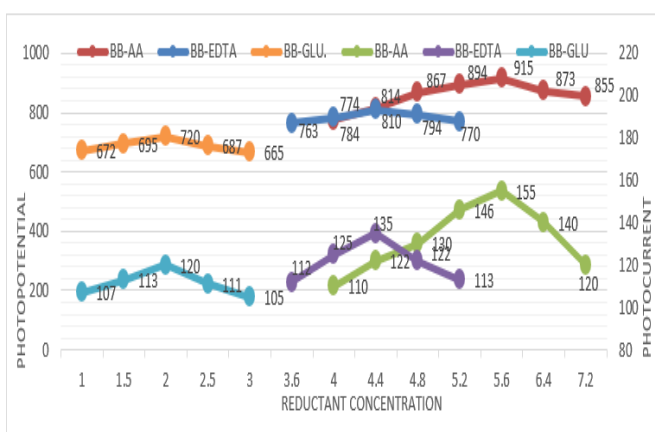
The needed pH was found to be larger than the reductant's pKa values in every example tested in this investigation (i)Enhanced dye solubility and lowered dye aggregation at higher pH ranges result in increased dye diffusion in the liquid electrolyte, (ii) enhanced solubility and lowered dye aggregation at higher pH ranges result in enhanced dye diffusion in the electrolyte solution, and (iii) enhanced solubility and lowered dye aggregation at higher pH ranges result in higher dye diffusion in the electrolyte solution, and (iv) the fact that dye reduction and full

solubilization need a pH range of 12.7–13. At pH greater than 13 (which implies a very high concentration of OH), the drop in current and power can be ascribed to an obstruction in the regeneration of the reductant original state due to a higher chance of OH ions recombination with the oxidised state of the reductant.

The oxidation potential of the reductant molecule and the reduction potential of the photosensitizer molecule influence the photo-reduction of the dye molecule in the presence of various reductant in different pH ranges. The effect of pH on the PG cell's electrical performance may thus be explained. The PG cell functions poorly at very low pH. At very low pH, the photosensitizer and reductant have weak electron donating power to the Pt electrode due to proton attachment to the heteroatom and double bonds in photosensitizer and reductant.

D. Variability's Effect of Reductant

When the concentration of three reducing agents was increased, it was discovered that Ascorbic Acid, EDTA, and Glucose was increased in different systems with Bismarck Brown as the photosensitizer, the output of these cells increased, reached In all cases, the maximum value was reached and then declined when the concentration of reduction agent was raised further. The dye-to-reductant ratio was maintained at 1:105-101 in these systems. The lower the reductant concentration, the lower the electrical output, The dye molecule travels slowly towards the electrode because there are less molecules available for electron donation, and the higher the reduction agent concentration, the fewer molecules accessible for electron donation. Graph 4 shows the effect of varying the concentrations of three reductant, Ascorbic Acid, EDTA, and Glucose, with Bismarck Brown as the photosensitizer.



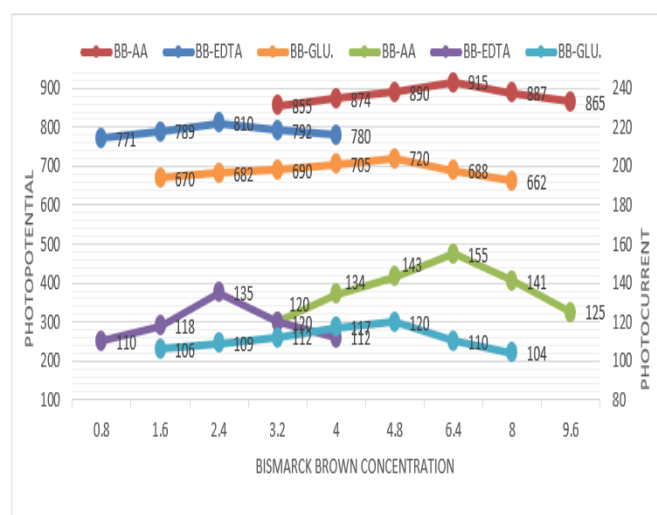
Graph 4. Shows Changes in Reduction agent Amount

At decreasing reduction agent concentrations, the number of accessible reductant molecules decreases, resulting in a decrease in the number of colour sensitizer molecules. As a result, the number of dye sensitizer molecules that can conduct electrons to the platinum electrode may be restricted, resulting in low cell power. Photon propagation and diffusion of excited dye sensitizer molecules towards the platinum electrode would be hampered by higher reductant concentrations, leading in lower cell

power. By favouring reverse electron processes from the sensitizer to the reductant, a larger number of reduction agent molecules may impair cell efficiency.

E. Variability's Effect of Photosensitizer (Dye)

When concentration of photosensitizer was increased, the photopotential and photocurrent increased as well. The level of photosensitizer (Dye) was controlled between 2.410-6 and 5.610-6 M for effective results in electrical output. There will be a limited number of photosensitizer molecules to absorb solar light in the cell at the lower end of the photosensitizer concentration range, resulting in low electrical output, whereas higher photosensitizer concentrations will prevent the desired intensity of light from reaching the photosensitizer molecules near the electrodes, resulting in the rapid drop in electrical output.. Influence of different Bismarck Brown concentration as a photosensitizer (Dye) has been shown in Graph- 5.

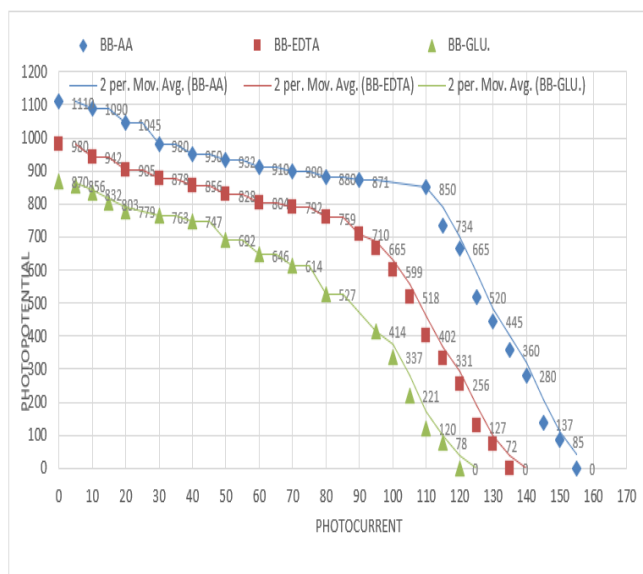


Graph 5. Shows the Impact of Bismarck Brown Variation

This might be due to a scarcity of dye photosensitizer molecules at lower dosages than the sensitizer's ideal concentration for collecting photons and transferring electrons to the illuminated chamber's anodic platinum electrode. Only dye sensitizer molecules that have been photo-excited and are near to the platinum electrode can reach the platinum electrode. Higher sensitizer concentrations do not enable enough photons to reach the platinum electrode, resulting in photo-excitation of fewer dye sensitizer molecules and decreased cell output.

F. The Cell's i-V Characteristics, Performance, and Power Efficiency

A digital pH device used for measuring the circuit voltage in open (Voc), while a micro-ammeter was used to measure the circuit current in short (isc) (having the other circuit off). The electrical parameters between these two extreme values (Voc and isc) were computed using a carbon pot (log 470K) linked in the circuit of a micro-ammeter via which an external load was provided. For all three systems, Graph 6 shows the equivalent potential value in relation to current values.



Graph 6. Displays the Bismarck Brown System's Current-Voltage(i-V) Characteristics

In i-V curves were found to differ from their expected regular rectangular forms in all systems. The point of power (the point on the curve where the potential and current is

higher) and factor of fill of i-V curves were determined. BB-AA system strength at point of power and factor of fill = 93.50 W and 0.54 percent, BB-EDTA system strength at point of power and factor of fill = 63.90 W and 0.48 percent, and BB-Glu. System strength at point of power and factor of fill= 42.16 W and 0.40 percent.

After discontinuing the illumination as soon as the potential reached a constant value, the performance of the pg cell was evaluated by applying an external load that was required to maintain current at the point of power. The output at point of power and the strength of incident radiations were used to calculate the efficiency of conversion of all systems. The systems were also exposed to light (under ideal conditions). These systems efficiency of conversion and sunlight conversion data are presented (1)Power, efficiency of conversion and $t_{1/2}$ for BB-AA system = 93.5 μ W, 0.899 and 40.0 min., (2) Power, efficiency of conversion and $t_{1/2}$ for BB-EDTA system = 63.9 μ W, 0.614 and 34.0 min. and (3) Power, efficiency of conversion and $t_{1/2}$ for BB-Glu. system= 42.1 μ W. 0.405 and 31.0 min. Table-1 summarises the key findings from several systems, Considering the current research's overall findings and illustrating the significance of these cells in relation to the sun energy storage.

Table 1. Summary of solar energy storage for different reducing agents using Bismarck Brown (BB) as photosensitizer

Observations	BB - AA System	BB - EDTA System	BB - Glu System
	Values	Values	Values
Open Circuit voltage (V_{oc})	1110.0 mV	980.0 mV	870.0 mV
Photopotential (V)	915.0 mV	810.0 mV	720.0 mV
Photocurrent of Equilibrium (i_{eq})	155.0 μ A	135.0 μ A	120.0 μ A
Maximum Photocurrent (i_{max})	198.0 μ A	180.0 μ A	170.0 μ A
Short circuit current (i_{sc})	155.0 μ A	135.0 μ A	120.0 μ A
Current at power point (i_{pp})	110.0 μ A	90.0 μ A	80.0 μ A
Potential at power point (V_{pp})	850.0 μ A	710.0 μ A	527.0 μ A
Power at power point	93.50 μ W	63.9 μ W	42.16 μ W
Rate of Generation	19.2 μ A min ⁻¹	15.3 μ A min ⁻¹	13.4 μ A min ⁻¹
Conversion Efficiency	0.8990 %	0.6144 %	0.4053 %
Charging Time	190.0 min.	180.0 min.	180.0 min.
$t_{1/2}$	40 min.	34 min.	31 min.
Factor of fill (n)	0.54 %	0.48%	0.40 %

According to the data, Bismarck Brown-Glucose System has the lowest i-V Characteristics of the Cell, Performance, and Conversion Efficiency, whereas Bismarck Brown-Ascorbic Acid (BB-AA) System has the greatest.

IV. CONCLUSIONS

The study's goal is to transform solar energy to electrical energy in the photogalvanic with the help of redox reactions, because the absolute cost of solar energy is now quite costly in contrast to any other source of energy, such as a non-renewable source. Bismarck Brown is a photosensitizer dye that is soluble in water. The dye is a suitable light-absorbing choice for dye-sensitizer PG cells because of these features. On the basis of observation, it can be stated that the sector of solar energy conversion and storage still has potential for

viability. More systems with higher electrical output, performance of cell, and cell storage capacity may be developed. The reductant and photosensitizer utilised in this study have clearly demonstrated that if the research is properly handled, cost and viability in all respects can be reached, and photogalvanic (PG) cell can have supremacy in the field of conversion, storage of solar radiation.

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