iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 Issue: IV Month of publication: April 2020

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue IV Apr 2020- Available at www.ijraset.com

Floatovoltaic Microgrids: New Possibilities of Decentralizing Water- Energy Sector in India

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Abstract: The uniqueness of India's high population density, low electricity consumption- poised for rapid growth, acute water scarcity differentiate it with the rest of the world and is making it tough for achieving sustainability and energy security. At present India is running the world's largest renewable energy addition program to reduce dependency on non-renewable fuel but a similar scale of program is yet to be started for water sustainability and security.

With over a billion still living in rural areas, the situation is worst for the availability of quality electricity and water. Fortunately, nature has provided abundant natural water reservoirs and resources for rural sustainability, which if maintained, preserved, and protected is sufficient for decentralized water availability.

This article examines the possibilities of floating photovoltaic solar plants for decentralize electricity generation while protecting natural water resources and designing a novel floatovoltaic microgrid in natural water bodies.

Keywords: Floatovoltaics, Solar photovoltaic, Microgrid, Electricity, Solar energy, Water.

I. INTRODUCTION

With over 3.28 million Sq KM area, which is hardly 2.4% of total world surface, India supports and sustains around 1.38 billion population which is 16.9% of world population among which almost 70% reside in the rural area. [1]

Average 135 litre per capita per day (LPCD) has been suggested as the benchmark for urban water supply. For rural areas, minimum service delivery of 55 LPCD has been fixed under Jal Jeevan Mission, which may be enhanced to a higher level by states. [2]

India also houses billions of animal population, which requires a significant quantum of water. Other than rivers and canals, total natural and manmade water bodies cover an area of about 70000 SQ KM. Among the remaining forms of the inland water resources, tanks and ponds have a maximum area (29000 SQ KM.) followed by reservoirs (21000 SQ KM.). [3]

The total amount of rainfall received annually is estimated at 400 million hectares meters (MHM), out of which 230 MHM goes back to the atmosphere as evapotranspiration, leaving 170 MHM to impregnate the rivers through surface flow (110 MHM) and regeneration (60 MHM). The temporal and spatial distribution of rainfall exhibits wide variations within the country. [4]

The annual utilizable water resources in India is 690 BCM from surface sources & 447 BCM from groundwater with the possibility of storing 214BCM of surplus monsoon runoff in the groundwater reservoir. [5,6]

India is undergoing the worst water crisis in its history and nearly 600 million people are facing high to extreme water stress. The report further mentions that India is placed at 120th amongst 122 countries in the water quality index, with nearly 70% of water being contaminated. [7].

People across India are facing critical drought conditions and water shortages. As of June 25, 2019, nearly 65 percent of the country's reservoirs were running dry. [8]. Till March, 2020, India's total electricity generation capacity stood at 367 GW_p, out of which renewable share is 132 GW_p with solar photovoltaic stands at 35.6 GW_p which is 9.6% of total installed capacity. [9,10]

India made significant growth in solar photovoltaic energy generation capacity addition and increased over 13 times capacity from 2.6 GW_p in the last five years, which also has significant numbers of over 0.659 million solar street light and over 1.8 million solar-home light. [11] Among various solar photovoltaic technologies, predominantly all installations are made either in ground-mounted or into rooftops, floatovoltaics are hardly 2.7 MW_p installations in India, however over 1.7GW_p is in various stages of developments with a potential capacity of over 280 GW_p. [12,13], Internationally, over 1.3 GW_p of Floatovoltaic solar is installed worldwide till 2018, this technology is poised for higher adaptability among all solar photovoltaic power plants. [14,34]

Floatovoltaic solar is not a new technology and was first installed a 447 KW_p solar plant in 2008 at Far Niente winery
in Oakville, Northern California with 994 solar panels on 130 pontoons floating at Nepa Vally Irrigation Pond at a cost of $ 4.2 million, producing more than 100% of the energy required using Thomson technology Industries Inc and Gopal Sankar, Recolte Energy as coordinator.

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In India, the first Floatovoltaic solar plant was installed in 2012 in a canal top in Gujarat.

Electricity is the most usable form of energy and development and life is not possible without electricity. Electricity transmission and distribution is possible only through the wire and economical consideration is very important for electrification, which incurs high cost. Microgrids are increasingly becoming important into technological & economical challenged areas.

India is unique because of the high rural population with over 645856 villages, low consumption of electricity with low penetration of electricity network, microgrids are important to make electricity available. [15]

In India, all the inhabited census villages across the country stand electrified as on 28 April 2018. The average electricity consumption per capita per annum is 1181 KW, which is far less than the world average of 2,674 KW, ranks at 104 among 140 countries, fairs poorly among all developed and several developing countries which clearly indicates that the consumption shall increase at a faster rate than at present and there is a need for capacity addition which in turn is possible by adding more renewable resources because of the benefits it provides. [16].

Solar photovoltaic requires significant area with $10KW_p$ plant requires around 100 SQM, which carries a cost and not easily available for microgrids because most of the lands are of agriculture type and not always suitable rooftops are available in the rural area. Additionally, Floatovoltaic near ponds and lakes help in electrification for agricultural lands.

India is having a huge pool of ponds & water bodies which also serves the purpose of providing non-drinking water needs. Due to climatic change, these water bodies get dried during non-rainy seasons also, creating water deficit.

The huge government challenge is duel as to provide electricity as well as water conservation, gives rise to the possibility of Floatovoltaic solar power plant, which gives multiple advantages and solutions for these problems.

Sustainability, a concept used to exploit natural resources without harming future generations, is being applied to power generation. Together with this concept of preservation and development of living beings, it can be considered that energy has been engaged to achieve sustainable development through renewable resources. Energy is essential to eradicate poverty, increase human welfare, and raise living standards. This research is undertaken to look for the possibility of answering these challenges and how Floatovoltaic microgrids can address these issues and why India should encourage Floatovoltaic solar-powered microgrids.

II. FLOATOVOLTAIC

Floatovoltaics or Floating solar or floating PV (FPV) plant refers to the installation of photovoltaic panels and its accessories on various unutilized, underutilized or utilized water bodies like natural & artificial lakes, reservoirs, hydroelectric dams, mining ponds, industrial basins & ponds, water treatment ponds, near coast lagoons, etc. Most of the floatovoltaics are mounting PV panels on pontoon-based floating structures, anchored to the bank or the bottom of the water body. Floatovoltaics solar is capable of operating on any freshwater, saltwater, or wastewater surface. Apart from technological advantages, the adoptability potential is very high as there are over 400000 KM^2 of man-made reservoirs on the planet which are not fully utilized with if only 10% is covered shall create over thousands of megawatts electricity generation. Floatovoltaics creates a blockage of solar rays hitting the water surfaces whose first layer of 50 cm absorbs about 50% of solar radiations thus the surface gets warmer than deep layers; the infrared part of solar radiation is absorbed in the first few centimeters of water, making water cooler and reducing the rate of evaporation, saves 15,000 m^3/year for each 10000 SQM of FPV Plant(Typically $1MW_p$ plant), and also increases the quality of the water. [17] The enormous need for renewable energies (especially PV), and the strong and vocal approaches of opinion-makers have pushed the market towards more trivial and simple solutions: roof and flatlands. These solutions are important but intrinsically limited and inadequate to take up the challenge of climate change, air pollution, and the depletion of stocks of fossil fuel. The high compact factor and the unlimited availability of water surface (freshwater or saltwater) suggest that the transition to floating plants in the PV technology scenario can have a dramatic impact on RES and can be the winning solution in the next few years. [18-19]

Several advantages are reported of the usages of Floatovoltaics solar plant like higher and better performance due to the water's inherent cooling nature, higher energy output, no or reduced land usage, no or less civil work, less shading and soiling, synergy with existing electrical infrastructure, complementary operation with hydro, reduction of evaporation loss, alternate energy at water bodies, the land space problem is reduced, has a lot of environmental benefits, storage opportunity, easy installation and decommissioning, improved plant load factor (PLF) due to the lack of a tracking system, etc to name few. [20-22,26,31,33,37]

Few disadvantages are also reported with Floatovoltaics solar plant like technological challenge, higher operation & maintenance cost, components need to be waterproof or else insulation faults may happen, corrosion and rusting, bird droppings, higher capital expenditure, lack of national and international experience, potential environmental, ecological and social impact on water bodies, etc. [20, 23,27,33]

III. COMPARISON WITH OTHER SOLAR PHOTOVOLTAIC TECHNOLOGIES

Floatovoltaics are not mature technology with the oldest commercial installation is in 2008. Worldwide hardly few GW_p installations are done with wide variation in installation techniques and still, sufficient research is not been carried out on all aspects. Present works of the literature suggest that Floatovoltaics solar plants are for viability and finding technological excellence and study all impacts rather than comparing the cost, ROI and instant tariff benefits for developing alternate solutions in the solar photovoltaic domain. [23-25,29,32,36]

Floatovoltaics Solar draws its similarity in all aspects of a conventional photovoltaic power plant with a major difference is that its panels are installed over water bodies using different techniques. Floatovoltaics can be either grid-connected, hybrid or off-grid, etc with all module technology like mono/ polycrystalline/ thin film, mono-facial/ bifacial, over the surface/ underwater, fixed axis/ tracking system, etc, can be deployed with comparable better results than rooftop or ground-mounted installations. Most of the research is carried out on experimental studies, floats, mechanical components, water evaporations, etc with little work on electrical designs. [28,30,31]

As the panels and its mounting structure, floats, anchoring systems, electrical connections, cables are in constant touch or submerged into water, the related components need to have higher insulation grade and corrosion resistant, however, most of the installations are made on freshwater reservoirs with little work on saltwater. [28]

IV. SOLAR PHOTOVOLTAIC MICROGRIDS

A microgrid is a group of interconnected electrical loads from a distributed energy resources within clearly defined electrical boundaries that acts as a solitary controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode. Microgrids are deploying with pioneering solutions and are powered by renewable energy to provide energy access for all. All these plants have mostly solar photovoltaic as electricity generators with a capacity range of few to several KW_p with or rarely without battery backup for providing backup for almost a couple of hours to over several hours. [39,40]

Microgrids are suited for best of its application and were in the US, most of the microgrids are installed in U.S. Department of Defence at its military installations as well as areas of severe or disruptive conditions like a disaster, etc, Africa and 3rd world countries including India sees as a vehicle for remote communication and basic electrification and in most of the microgrids, telecommunication load is anchor load with balance been distributed among other government installations like banks and to general lighting loads using battery storage and DG sets(in some cases).[19]

Mini-grids have a unique feature as they can operate autonomously without being connected to a centralized grid. However, mini-grid has flexibility in designing for its interconnectivity with the central grid which means it can operate under normal conditions as part of the central grid, with solar as a priority and its disconnection occurring only if power quality needs to be maintained. For instance, in the case of a central grid failure, microgrids support grid-connected consumers for its surplus energy. Alternatively, a mini-grid may be designed to operate autonomously in a remote location with the option to connect to a central grid when grid extension occurs. Microgrids are seen as a mode of increasing the reliability of electricity supply. Due to their small scale and enhanced local level ownership of physical infrastructure or management, power theft which is commonly associated with centralized on-grid systems can be reduced. [38]

The reliability of supply is generally greater with hybrid microgrid systems compared to a standalone or grid-connected technology. This not only lowers the net costs over the lifetime of a project but also ensures the availability of electricity when either or both grid and solar system is not working. [35]

There is an environmental improvement from the use of microgrids. This is in terms of efficiency and reduction in carbon emissions. Hybrid microgrid systems, for example, often incorporate a 75-99% renewable supply with the removal of the need for highly polluting and ecological degrading Diesel Generator sets.

For India, where the grid system is not well matured with the quality of electricity supply a major concern in the non-urban areas with a vibrant private sector, microgrids provide immense opportunities and they are adaptable due to the fact that it can be connected to the grid. [41,42] Microgrid systems are becoming more economically attractive due to the rise in oil prices with OPEX cost and the cost of renewable energy resources getting decreased. However, subsidies are still required for the different schemes but they are a smaller percentage of the investment than on-grid subsidies.

Despite these opportunities with microgrids, their penetration still remains low in India and across the world and still not reached full potential exploitation. Progressive development in microgrids has been greatest in China where there is but in Nepal, India, Vietnam, and Sri Lanka only less than a thousand microgrids each.

Common challenges for the implementation of microgrids include lack of maintenance or the use of poor quality or untested technology. This could be a lack of sufficient funding to sustain the project over its lifetime or the shortage of local skills for maintenance of the mini-grid.

Poor assessment that is mostly compounded by lack of data on the local physical parameters that affect the power output and economics including population density within the location of the mini-grid, will have an influence on the load factor as well as the overall economics of the mini-grid.

Type of terrain will have an impact on the various resources required for the mini-grid i.e. the cost of infrastructure, fuel cost (for diesel systems) as well as the operation and financing of the system. [43]

Seasonal resource fluctuations- This includes solar Insolation, wind speed fluctuations, and river flows.

Future policies- these policies are important in determining the future investment capacity in renewable energies, as an example, it should include suitable sites and an ambitious rapid rural electrification program.

Development of schemes without attention to developing supplementary programs dealing with issues such as market access, small-medium enterprise (SME) development, and working with local financing institutions, has contributed to a lack of demand and inability to sustain the schemes.

V. FLOATOVOLTAIC SOLAR ENERGY GENERATION: A NEW CONCEPT

Several patents were filed during 2007-08, the world saw several firsts in Floatovoltaic solar installations with Japan and China leading the race followed by several countries including India.

2007, World's first floating solar plant built in Aichi Prefecture in central Honshu.

2008, World's first commercial floating solar plant built Far Niente winery in Oakville, Northern California

2014, the world's first floating, rotating solar voltaic power plant with a capacity of 465 KWp on the Geumgwang reservoir in Anseong, Gyeonggi Province.

2014, the world's first floating solar power plant for the marine environment.

2016, the world's first plant larger than 10 MW_p was installed.

2018, the world's first and several plants larger than 100 MW_p were installed, the largest of which is 150 MW_p.

VI. FLOATOVOLTAIC MICROGRIDS

While across the globe the endurance is towards the bigger size of Floatovoltaic solar plant for reaping the benefits of a bigger scale, small size Floatovoltaic microgrids are conceptualized as floating solar panels in small water reservoirs providing electricity to the localized area with or without an option of scalability, while conserving water bodies. Small water reservoirs can be small ponds, lakes, etc situated near the cluster of loads. In India, where almost a billion of the population resides in over 645 thousand villages, the opportunities it proposes are immense as it helps in conserving available water and providing electricity professing decentralized living in the diversified area to answer local level challenges of providing electricity, water, avoiding electricity theft, generating local employability, reduce transmission and distribution losses.

VII. BENEFITS OF FLOATOVOLTAIC MICROGRIDS

Several benefits are associated with Floatovoltaic microgrids in Indian context as it addresses several water- electricity challenges at one go.

There is acute water scarcity in India with only 35% of water sufficient reservoirs. Floatovoltaics by blocking almost 50% direct solar irradiance of the total occupied area, keeps the water temperature below evaporation level and keeps it conserve.

Possibility of installations of Floatovoltaics microgrid increases due to the availability of unutilized water surface thus saving land area, which can be utilized other purposes including irrigations etc.

Capital cost and operation & maintenance cost of transmission and distribution of electricity reduces significantly as Floatovoltaics microgrid uses the local distribution network and also a handful for agriculture electricity needs, due to possible proximity. The possibility of installation in remote and technical nonviable regions is very high, especially to hilly areas or forest enclosed areas where inhabitations are only supported by lakes or ponds.

Complete removal of diesel-based generators which are also ecologically damaging.

Possibilities of implementation of electricity based transportation for last-mile connectivity which shall improve communication. Holistic development by way of regular communication, higher employability, etc.

VIII. CONCEPT DESIGN OF FLOATOVOLTAIC MICROGRID

A representative diagram of hybrid 30 KW_p floatovoltaic microgrid plant is provided which consists following major components-
This proposed plant is having following input parameters-

1) *Place:* Kali Pokhar, Sarath, District- Deoghar, Jharkhand, India- 814149
2) *Latitude & Longitude:* 24.2346^0 N, 86.8383^0 E
3) *Annual Rainfall Status:* In 2019, total rainfall 1174 mm with declared draught affected area with 30% less rainfall with last 10 years average at less than 500 mm.
4) *Sunny Days:* 325 days
5) *Maximum wind Speed:* 30 KMPH, Basic Wind Speed (As per IS 875, Pt-III)- 39 KMPH
6) *Shade Free Area:* ≤ 500 SQM, Designed Floatovoltaic Solar Power Plant Area:- ≤ 300 SQM
7) *Targeted Population:* 300 Households and few commercial & institutional customers.
8) *Designed Floatovoltaic Solar Power Plant:* 30KW_p

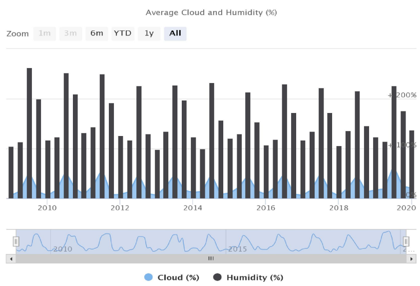

Fig: 1

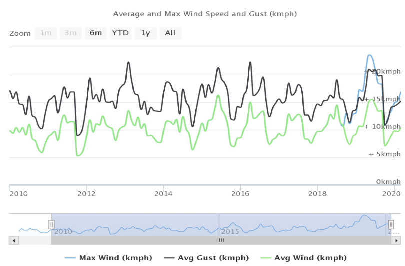

Fig: 2

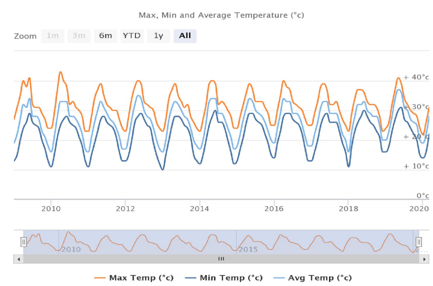

Fig: 3

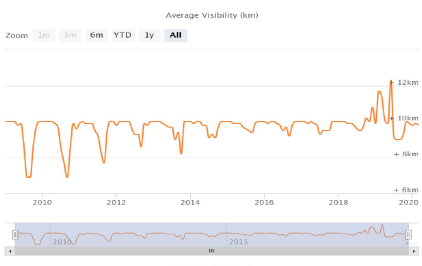

Fig: 4

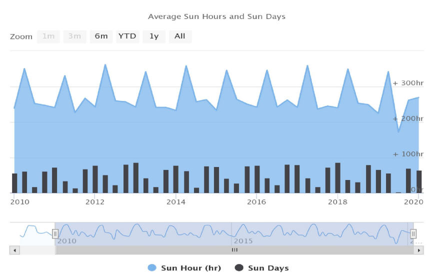

Fig: 5

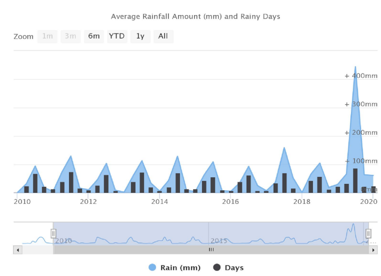

Fig: 6

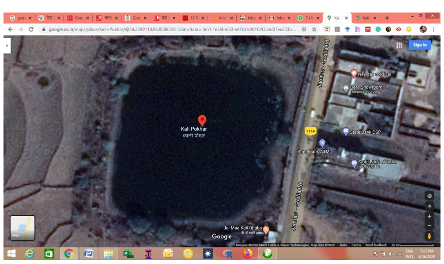
Fig: 7


Fig: 8


Fig: 9

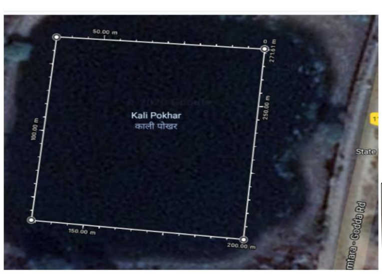

Fig: 10

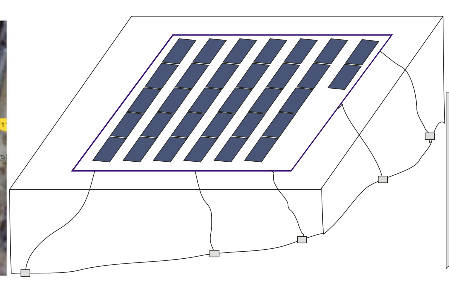
Fig: 11

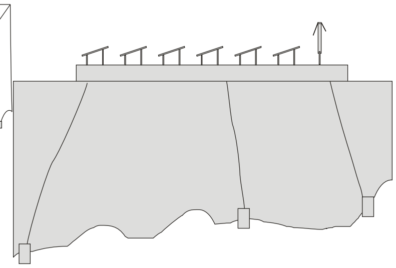
Fig: 12

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Volume 8 Issue IV Apr 2020- Available at www.ijraset.com

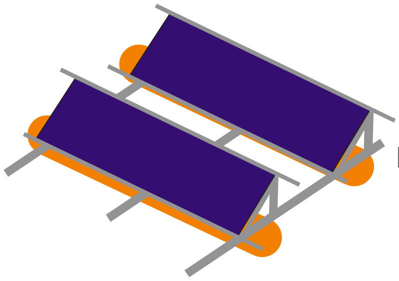

Fig: 13

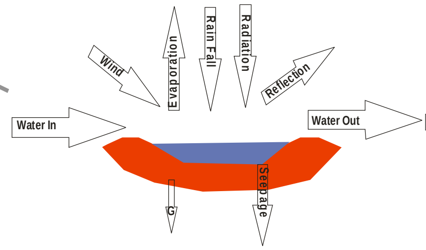

Fig: 14

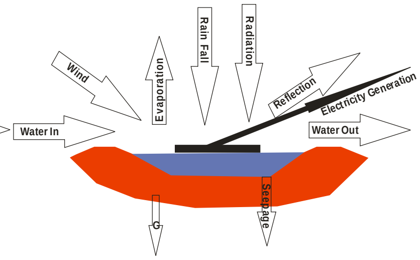

Fig: 15

Fig: 1- 6- https://www.worldweatheronline.com/lang/en-in/deoghar-weather-averages/jharkhand/in.aspx
Fig: 7-10-https://www.google.co.in/maps/place/Kali+Pokhar/@24.2399831,86.8385053,…….
Fig: 11-15- Self Designed

SN	Name of the Component	Quantity	Technical Details
1	Solar Photovoltaic Panel	100 nos	335W_p, Poly Crystalline
2	Power Conditioning Unit	01 nos	30KW 3φ Hybrid Inverter
3	Module Mounting Unit	06 nos	80Micron Hot Dip Galvanized Iron with anchors
4	Mooring Systems	10 nos	Chain Cable Method
5	HDPE Float/ Pontoon	30 nos	Main and Secondary Float, 20^0 Tilt Angle
6	Rechargeable Battery	30 nos	12V150Ah Tubular Lead Acid Battery
7	Array Junction Box	01 no	DC Combiner Box, 5 in-1 out
8	AC Distribution Box	01 no	AC Distribution box, 3φ, 1 in- 1 out
9	Bi Directional Metering Unit	01 no	Grid Exportable metering Unit
10	Data Logging Unit	01 no	IOT Based for online remote monitoring
11	AC Cable	50 M	3C+N, 50 SQ MM armored Al cable
12	DC Wire	200M	4 SQ MM single core multistrand solar grade copper wire

The lists of major components are mostly similar to the existing solar photovoltaic system whose technologies are already matured now with exception of floats and other module mounting structures.

IX. SUMMARY AND CONCLUSION

The Floatovoltaic microgrid, which is a decentralized photovoltaic system into an existing water bodies, located near rural and remote areas and integrated with or without an existing grid and equipped with or without energy storage systems shall merge smoothly into the existing infrastructures with minimum environmental impact. The benefits are multipronged with higher goal of achieving water- energy sustainability for rural and remote locations across India.

Being a new concept sizeable installation across the various geographical region is to be carried out and a techno-economic-environmental assessment on various parameters such as its technical suitability on different environment, effect of light incidence in different quality of water, algae growth, and oxygenation, the effect on aquaculture, etc should also be performed by monitoring and analyzing its effect with comparative results with other forms of solar photovoltaic systems.

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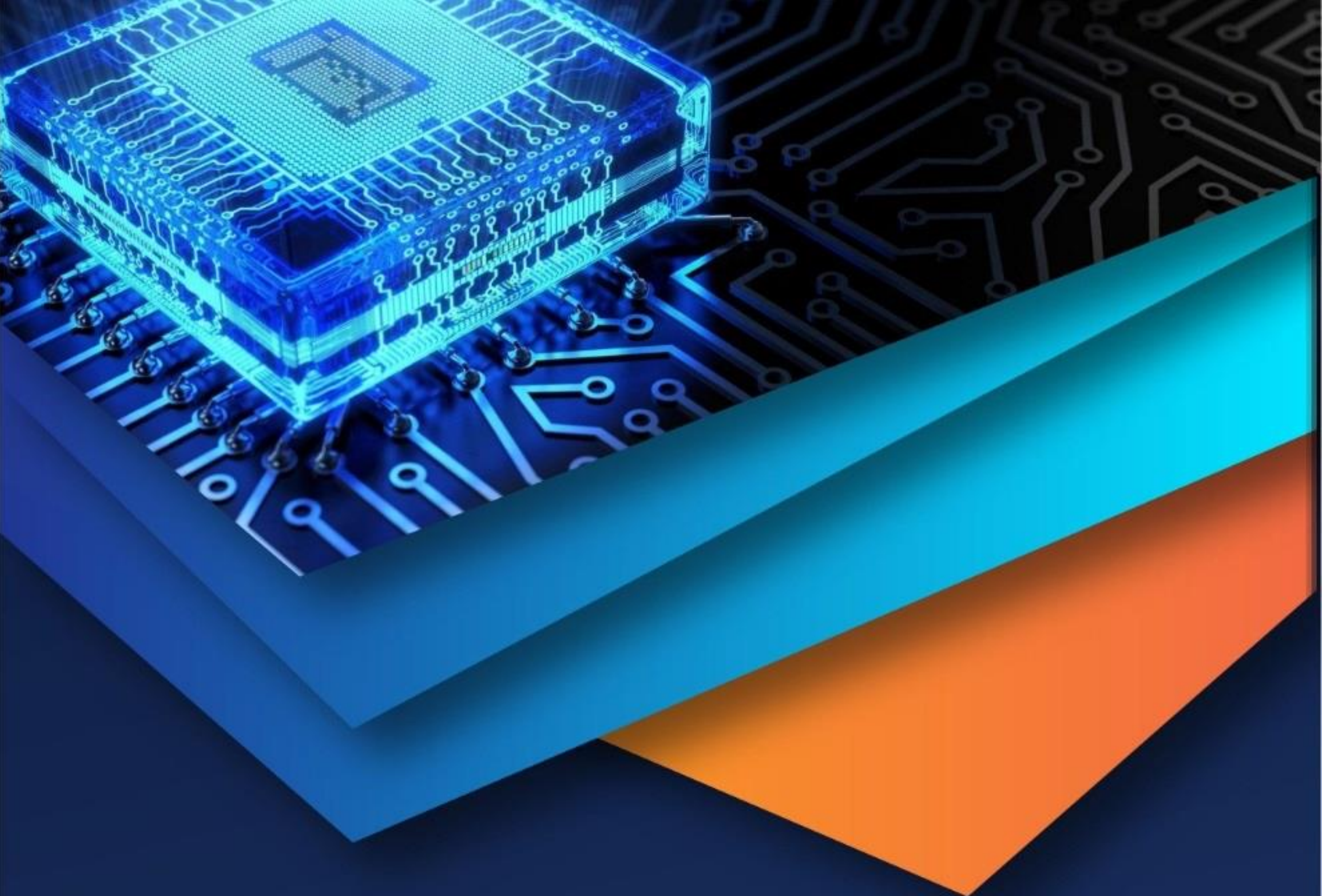

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