iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** VIII **Month of publication:** August 2022

DOI: https://doi.org/10.22214/ijraset.2022.46398

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VIII Aug 2022- Available at www.ijraset.com

Experimental Study on the Effect of Soiling at Various Tilt Angles of Photovoltaic Modules

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Abstract: ***Power generation from a solar photovoltaic system is one of the glowing research fields these days, even governments are also planning toward installation and production of power generation from renewable energy sources because in the future its feasibility and crisis of conventional energy sources will increase. Further government liberalization and technical developments vitalize the use of renewable sources for electricity generation in terms of solar power. In any power production plant, improvement in the efficiency of the plant is a big and important issue. After installing the solar power plant, it is very urgent to get maximum performance from them. With all other factors, the tilt angle and azimuth angle affect the efficiency of the plant. Thus, it is very important to orient the solar modules at optimum tilt angle and azimuth angle for any given location because they are most efficient when they are perpendicular to the sun's rays. A comparison study was executed to achieve the power variation and dust deposition with different tilt angle in natural environment of Ajmer. Powers generated by solar cells over study period are in range of 5.10W and 3.0W. It is evident that Solar module tilted at 26^0 generate higher power than Solar module tilted at 0^0 tilted module, followed by Solar module tilted at 45^0.***

Keywords: solar photovoltaic, conventional energy sources, Tilt angle and azimuth angle

I. INTRODUCTION

The surface of the earth is acquiring approximately 1018 kWh/m^2 of solar radiation every year [1], but is hardly use just around 1/6000 of that bulk [2]. To take the advantage of incoming solar radiation, the solar module must be installed at the optimum tilt, without disturbing our planet**.** The Earth moves around the sun and spins also so the sun's positions at the different parts of the earth vary. Due to this motion solar radiation coming from the sun depends on geographic latitude, season, and time of a day [3]. Many studies have been developed to decide the optimum solar energy collector orientation. When focusing on maximum annual irradiation on an inclined surface, it is mostly proposed to orient the collecting surface toward due south with a tilt angle equal to the latitude of the geographical location. Such theoretically derived suggestions are based on direct radiation only, and practical experience recommends that when diffuse radiation is involved, different results may be obtained [4]. There are various methods are available in the literature for solar module installation for mounting.

II. LITERATURE STUDY BASED ON DIFFERENT TILT ANGLES AND ORIENTATION

The tilt angle and orientation of the PV modules are major factors that affect the efficiency of PV modules. It has been noticed that for every site on the planet with specific radiation aspect, there is an ideal tilt angle for the highest solar energy reception. By the Japan Meteorological Agency, solar radiation data has been assessed for about 60 sites to find optimal tilt angle and provide enlarged AMeDAS Weather data for 842 places in Japan. Some theoretical research has been performed regarding the optimal tilt angle using these data [5]. Data related to hourly diffused solar radiation and average incident radiation with tilt is collected at Delhi, India [6]. G. Hegde and T.V. Ramachandra collected energy requirement data for Kerala and Karnataka and then sector-wise solar energy consumption rate is explained in south India [7]. Various techniques and technology are being investigated to estimate the radiation on tilted surfaces [8-11]. R. Tang and T. Wu in his research for an optimal angle of solar surface predicated that intensity of solar radiation is higher for optimum angle in comparability to the horizontal surface [12]. Energy reception rate for different orientation is different according to the distance of the location from the equator and in southern hemisphere, the north face collector gains more power in comparison to any other orientation [13]. M. Lalwani et al. in India studied the size optimization of the SPV system under local climatic conditions. They reported that time duration of study, tilt angle, location of the site, and solar module orientation are the crucial factors for performance deviation of solar modules [14]. Research activity for estimation of tilt angle for different locations is performed by eminent researchers since optimal tilt angle is hung on the latitude of the location, climate condition, and surrounding hurdle. Generally, the latitude angle of the site is considered as the tilt angle of that particular location on the condition that the clearness index is nearly the same during the year [15]**.**

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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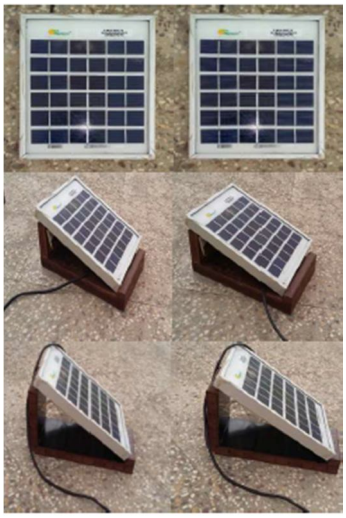
III. METHODOLOGY

In this work we have taken total six mini solar modules and six wooden frames. These frames are manufactured in this way that as module is placed on them then there is zero-degree, twenty-six degree and forty-five-degree tilt from the plane surface.



Two sets are placed for 0^0, two for 26^0 and another two for 45^0. From each set one module is cleaned every alternate day and other is kept without cleaning. Hourly data for radiation, module temperature and wind velocity were monitored and recorded for every one hour. This work is continued for almost forty-five days (Feb-March) and for 9:00 AM to 4:00 PM. A comparison study was executed to achieve the power variation and dust deposition with different tilt angle in natural environment of Ajmer**.** Voltage and current for three tilt angles 0^0, 26^0, and 45^0 of south faced polycrystalline silica PV modules are recorded. Another set of solar modules left unclean to study the effect of dust on the different tilt angles. All six modules have similar specifications with a rated power of 6W, Voc=12V, Isc=0.5A, and tolerance of 10%. A multi-meter is used to record the voltage and current of the modules. Solar irradiance is recorded using the solar meter. To find the quantity of dust depositing onto the glass surfaces, the glass plates with the dimension of 25×15 cm2 of 2 mm thickness are placed on 00, 260, and 450 tilted another wooden frame. To measure the dust load on these three glass plates, they are carried delicately and weighed under controlled conditions by the use of an electric balance with a precision of 0.001 g. The samples are weighed every seventh day for six weeks. The weight of the dust particles accumulated on the glass is calculated from the increase in the weight of the original cleaned glass plate.

IV. OBSERVATIONS

For optimal orientation, the PV modules are holding on facing south. In this work, the module was tilted at a different angle like 0^0, 26^0, and 45^0. First, the hourly data for irradiation, temperature, wind velocity, voltage and current are recorded for each day starting from 1st Feb to March 15th. Then, the average is calculated for those values.

From the measured value of voltage and current, power values for different tilt angles and for clean and unclean modules are calculated.

V. GRAPHICAL ANALYSIS

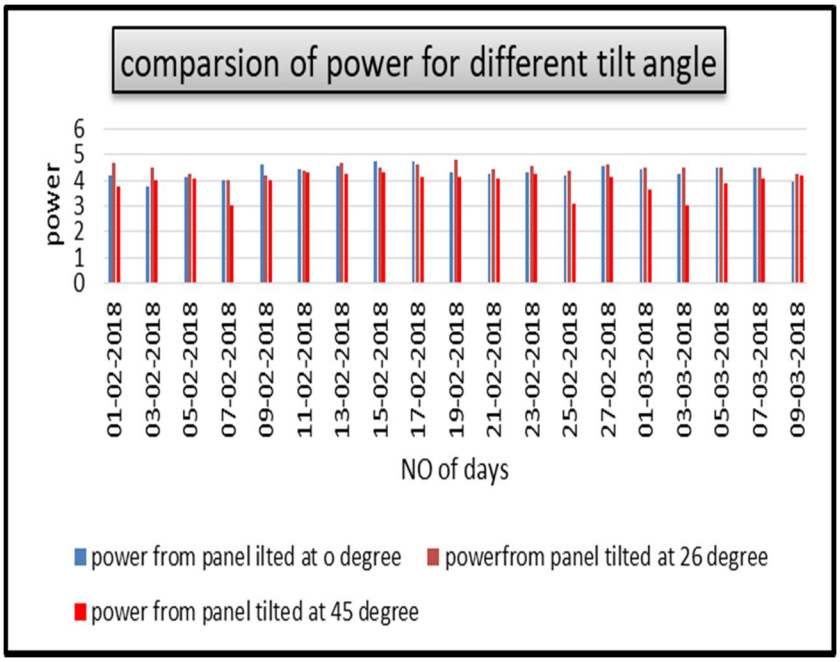


Figure 1: Comparison of power from unclean modules at different tilt angles

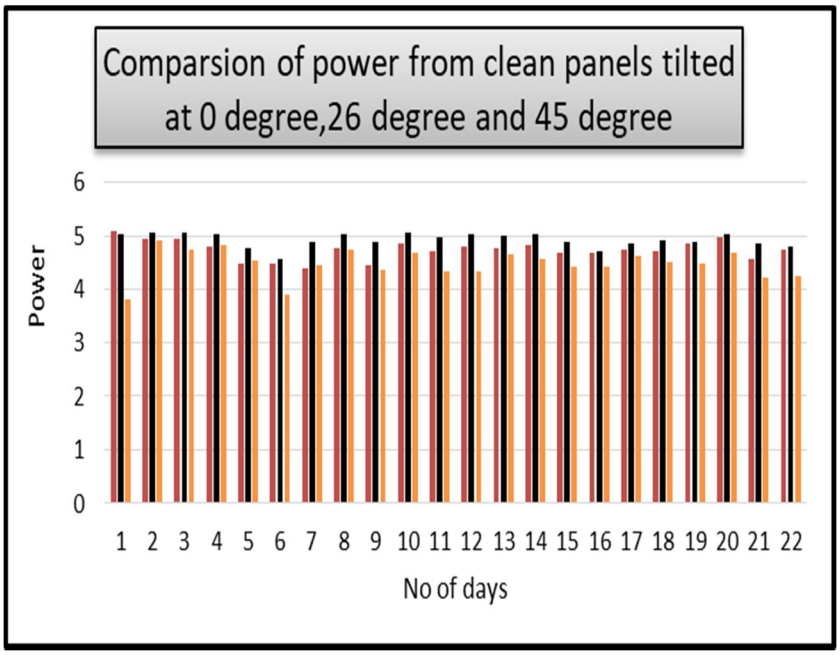


Figure 2: Comparison of power from clean modules at different tilt angles

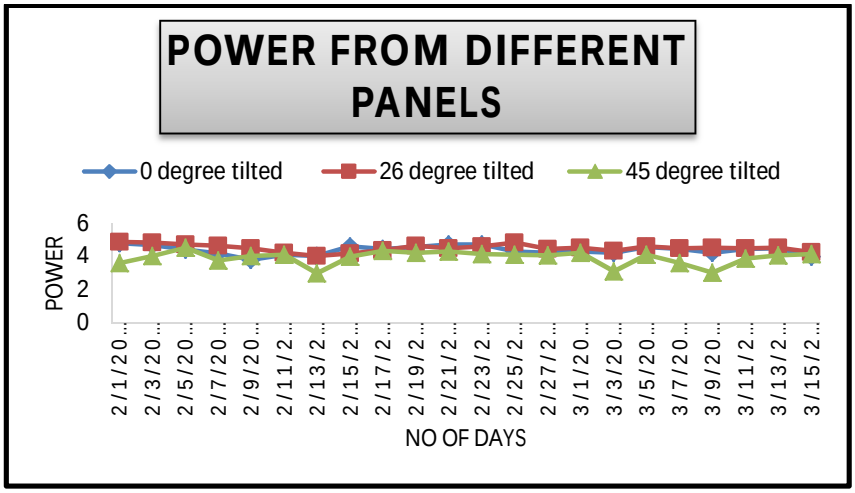


Figure 3: Comparison of power from unclean modules at different tilt angles

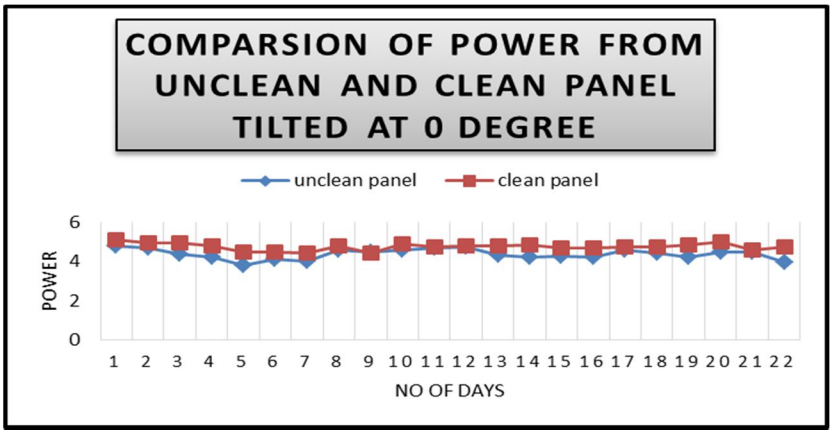


Figure 4: Comparison of power for unclean and clean modules tilted at 0 degree

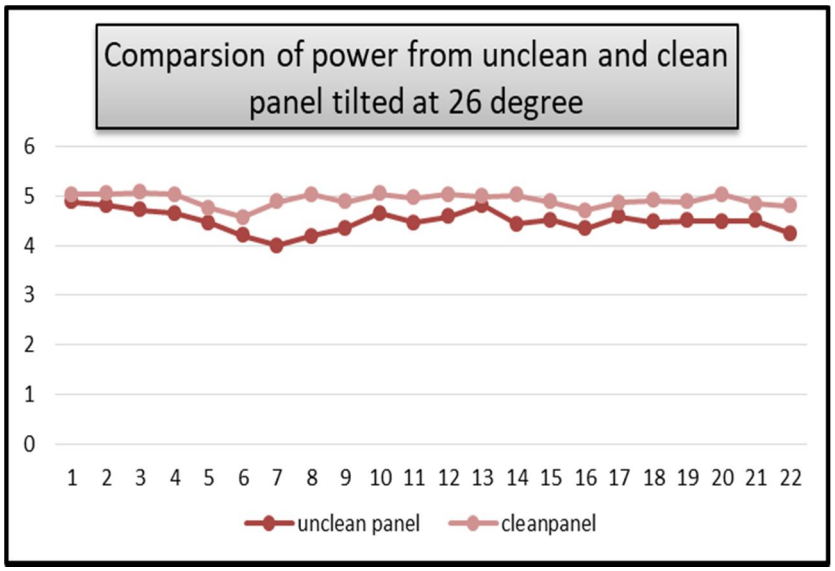


Figure 5: Comparison of power for unclean and clean modules tilted at 26 degree

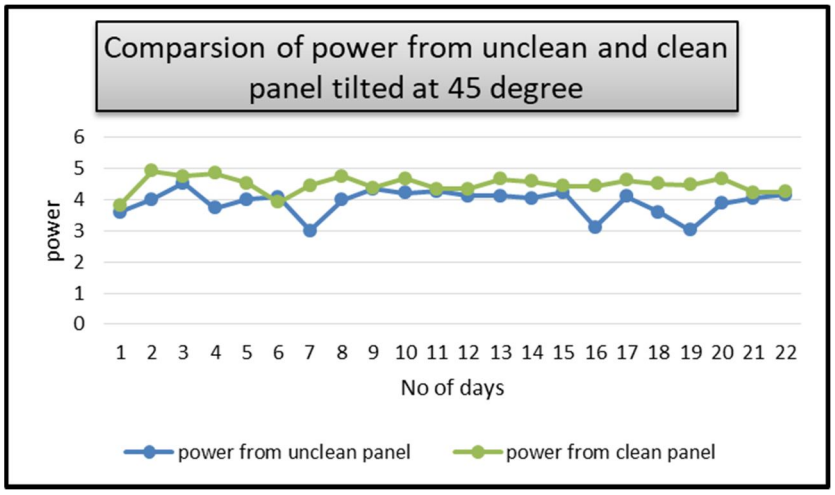


Figure 6: Comparison of power for unclean and clean modules tilted at 45 degree

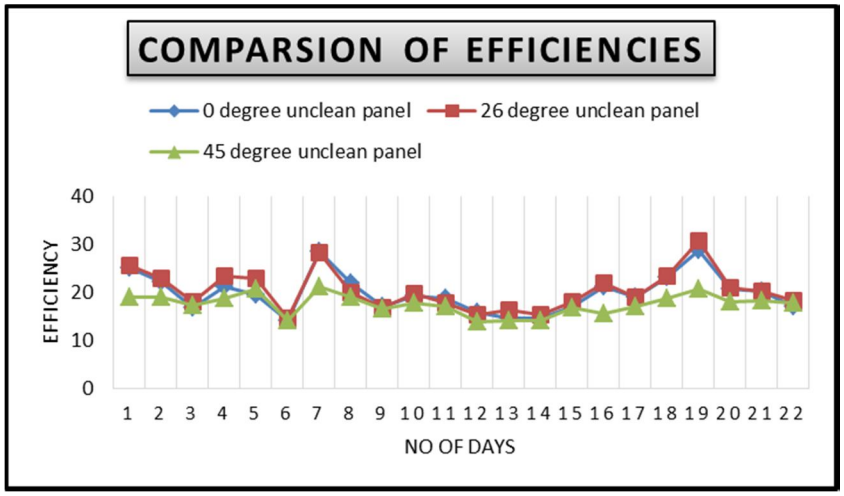


Figure 7: Comparison of efficiencies of unclean modules at different tilt angles

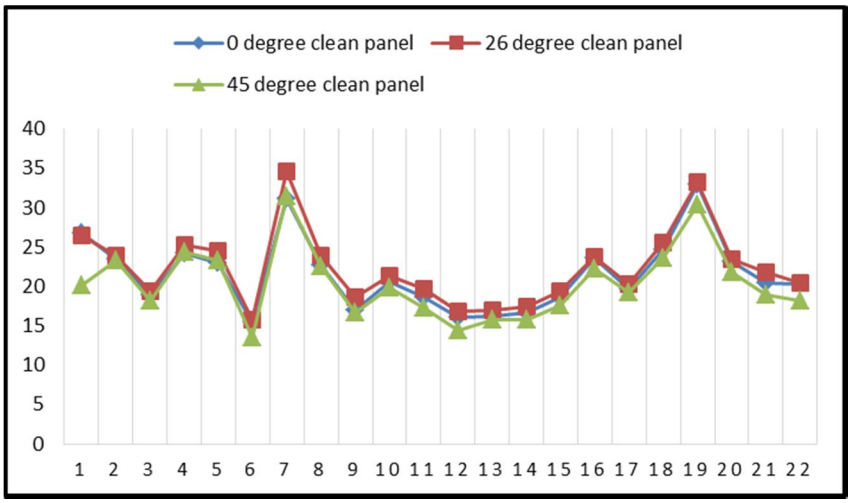


Figure 8: Comparison of efficiencies of clean modules at different tilt angles

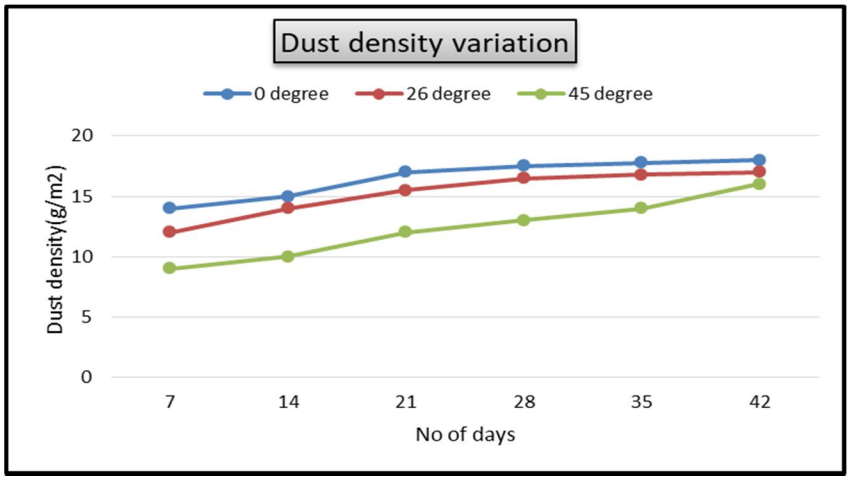


Figure 9: Dust density variation with number of days for 0^0, 260 and 450 tilted modules.

VI. RESULTS AND DISCUSSION

Power generated from 0^0, 26^0, and 45^0 tilted unclean modules is plotted against the duration of the study in Fig. 1 and Power generated from 0^0, 26^0, and 45^0 tilted clean modules is plotted against the duration of the study in Fig. 2. Powers generated by solar cells over study period are in range of 5.10W and 3.0W. It is evident that Solar module tilted at 26^0 generate higher power than Solar module tilted at 0^0 tilted module, followed by Solar module tilted at 45^0 .The purpose of the study is not associated with the optimization of the tilt angles so no attempts are done to perceive the effective tilt angle β. The highest efficiencies calculated at 26^0 inclinations for clean module is 34.54% and for unclean module is 30.68%. The lowest efficiencies calculated at 45^0 inclinations for clean module is 13.76% and for unclean module is 13.55%. From Fig.9 it is clear that the deposition density on all orientations increases with prolonged exposure and 0^0 plates has more affinity for dust deposition than 26^0 and 45^0 degree plates. Dust deposition density changes in a range of 09 g/m^2 to 18 g/m^2. As the dust density increases the loss in power increases.

VII. CONCLUSIONS

Ajmer, India experiences good solar irradiation with an average of about 800 W/m2 on an average from mid-Feb to mid-March. So, there is a good scope for utilization of solar energy. Power generated from all modules show gradual decline in production with reduction in solar radiation for a particular period. Because of the continuous and periodic change in the sun's location, Fixed Tilt angle mounting of the solar modules affects the electricity production capacity of the system. From comparative study between unclean and clean PV modules tilted at various angles it is observed that 26^0 clean modules register considerably superior power and efficiencies.

VIII. ASSUMPTIONS AND LIMITATIONS

The test station was set up at the S.P.C. Govt. College, Ajmer. Since the outdoor soiling results were obtained only at one location, they may or may not be applicable to other climatic conditions. Energy harnessing from solar photovoltaic is influenced by different factors and all of them should be taken into the studies, for comparative analysis and interpretation of the data, to obtain valid results.

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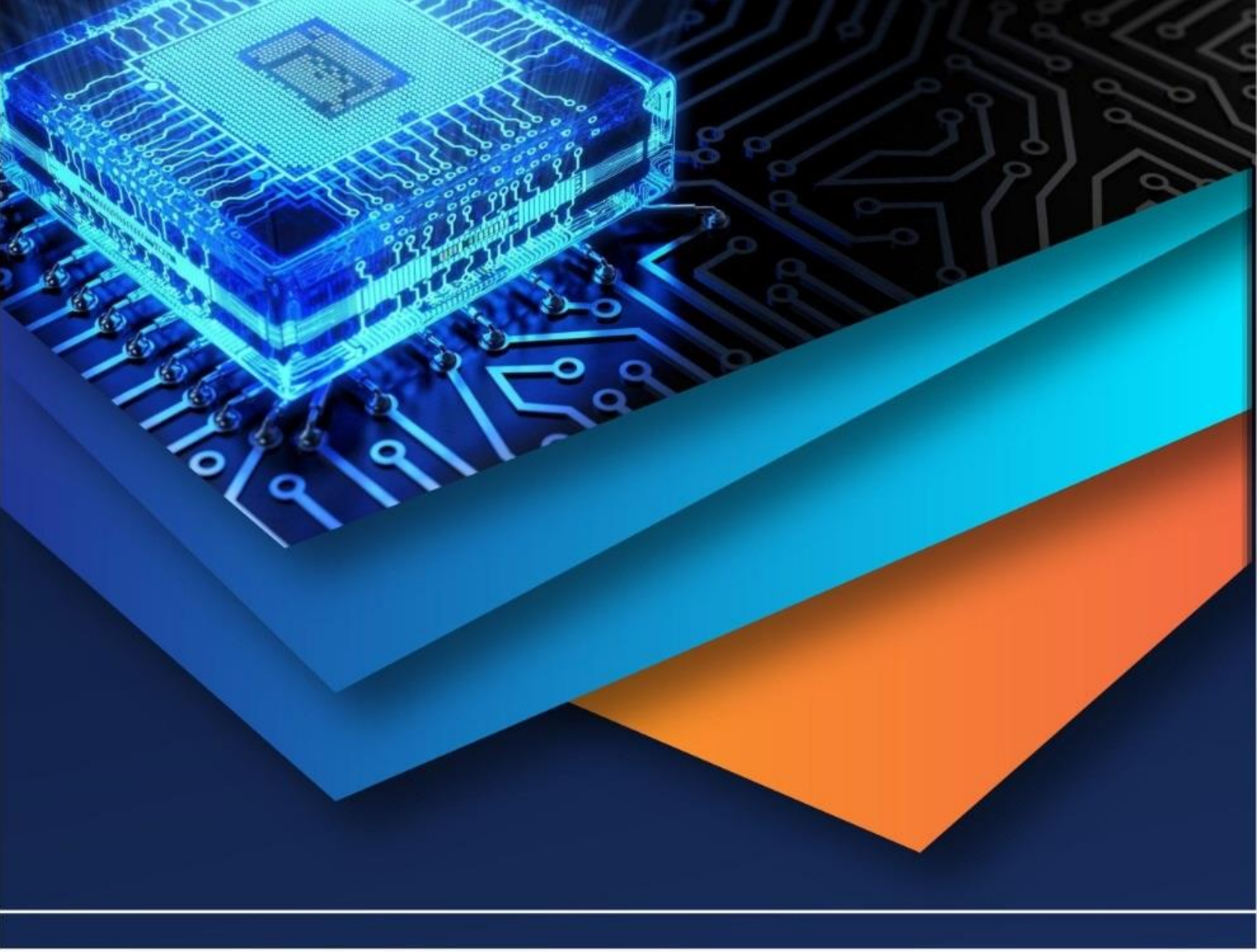

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