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Performance Estimation of Polycrystalline Photovoltaic Module during summer

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Abstract: The earth receives quiet, infinite, and non-polluting energy in the form of electromagnetic radiations from sun. There are a number of techniques to utilize this copious source of energy to full fill energy demand. World is struggling to come out of non-renewable energy sources which are costly and insecure (nuclear energy). This paper represents the meticulous performance evaluation of commercially available photovoltaic (polycrystalline) module during summer months (May, June July and August) in Faisalabad, Pakistan. The experimentation was carried out at al fresco conditions. Power output, module efficiency and performance ratio were observed for the polycrystalline module and effect of solar irradiance and temperature on these parameters were investigated. Solar irradiance and temperature were major factors disturbing the consistency of photovoltaic module. Polycrystalline module has shown improved performance in high irradiance conditions but at low plate temperature, while it decreased abruptly with the decrease in irradiance. The photovoltaic module also showed the decline in efficiency and performance ratio with the increase of temperature.
Keywords: Solar cell, photovoltaic module, STC, Temperature Coefficient, Performance ratio, Module efficiency.

I. INTRODUCTION

Checking the performance of photovoltaic modules at al fresco environment is mandatory to have a correct evaluation of output of PV modules under particular climate. The maximum flux density of solar radiation reaching the earth surface is 1000W/m2 and in the wavelength band of between 0.3 and 25 µm.[1] The parameters given by manufacturing company are observed on the standard test conditions(STC) which do not give the same values when observed at outdoor conditions This is due to varying outdoor conditions from STC. [2] .In the early 1990s, researchers commenced developing methodologies to guess module working under real operating environment.[3] P.E. Ugwuoke and C.E. Okeke conducted experimentation at Nigeria's university located at Nsukka (397 meters above sea level). They studied the performances of the modules in terms of their rated and observed variables (Voc, Isc, Imax , Vmax, Pmax, and ή (Efficiency)) as function of global solar irradiance. They concluded that the observed efficiencies were too much lower than given by manufacturer or rated values.[4]Amin and others performed an experimental study to assess the performance of four PV modules (monocrystalline, polycrystalline, a-silicon and copper indium gallium (di)selenide in Malaysia for three repeated days. The results revealed that copper indium gallium (di)selenide module has higher performance ratio(PR) while mono crystalline (c-si) module has highest module efficiency among all themodules tested.[5] Muhammad Ansar Bashir et al conducted a complete study to check the performance of three commercially accessible PV modules for consecutive three months (Jan, Feb and March) of winter season in Taxila, Pakistan. They concluded that there is a linear relationship between solar irradiance and power output. Their study had also revealed that crystalline silicon (c-si) module has exposed high average output power but a-Si has shown higher accommodated output power efficiency due to its greater performance in low solar irradiance. [6]Performance and analysis of different photovoltaic technologies was taken by Earth Science and Technology University of Hawaii at two different sites Puu Waa Waa (PWW) and Hawaii and Green Holmes Hall Initiative (GHHI), Oahu. The efficiency of Polycrystalline module at STC was 13.9% at PWW, Hawaii and for weather conditions of GHHI, Oahu was 13.8%. [7 -8]The result of solar irradiance on the output of PV modules was investigated by the different researchers. The effect of temperature on PV module also found by a number researchers.[9]Dr. M. Narendra Kumar and his companions observed the effect of solar radiation wavelengths on the efficiency of PV modules. They find that the power generation depends on the light wavelength if the wavelength goes on increasing power also increases.[10]The rate of photon generation increases with the increase in temperature thus reverse saturation current increases quickly and this results on decrease in band gap. Hence this causes the current

to increase linear and voltage to exponentially. [11-12]Some other inevitable ecological factors including dust accretion, wind speed, humidity and atmospheric temperature also affect the performance of PV modules. [13] The theoretical model estimated by Cristaldi et al used to predict the impact of dust from economical point of view.[14] Mekhilef et al conducted the examination of effect of humidity, dust and air velocity simultaneously. They made that the effect of each parameter could not be studied separately during the estimation of cell evaluation by avoiding others.

[15]According to available literature about solar potential in Pakistan, the average every day sunlight hours in many areas of country are ranging 7-8. [16]In Pakistan the daily average global solar irradiance is 19- 20 MJ/m2/d and mean annual solar irradiance is 15–21 MJ/m2. The very essential reason of our study is to evaluate the performance of polycrystalline module over summer months (May, June, July and August) and to scrutinize the effect of module's temperature, global solar irradiance on the yielding parameters of PV unit.

II. MATERIAL AND METHOD

The polycrystalline PV module was under observation in this study. The module rated at 295W and 36V. A 3KΩ variable resistor served as a load in this study. An efficient digital ammeter (CT, DT830D), high resistance digital voltmeter (UNI-T, UT33B) used to measure output current and voltages. We also used a pyranometer SM206 (Accuracy of 10W/m2, Resolution of 0.1W/m2 and range of 0.1-3999 W/m2) to measure solar irradiance. A K-type thermocouple with digital display was attached at the center of the module to measure its back temperature.

III. EXPERIMENTAL SETUP

The experimentation was carried out at Faisalabad (Latitude: 31.4167 Longitude: 73.0833), Pakistan. The solar module was tilted at an angle of 35 degrees from the horizontal plane on the roof top. The ammeter was connected in series and high resistance voltmeter in parallel to form the circuit. A variable 3KΩ variable resistance or load was used to check at which point the module shows its maximum output power. I-V curve drawn through measured current and voltage data provided the module parameters Pmax, Imax and Vmax. The circuit diagram is shown in Figure 1.

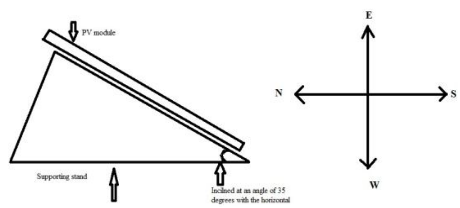

Figure 1: Positioning of photovoltaic module showing direction towards sun (South) and tilted at an angle of 35 degrees with the horizontal

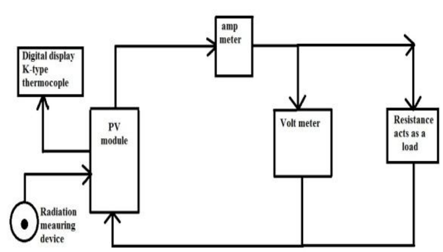

Figure 2, shows the schematic diagram of experimental setup

IV. MEASUREMENTS

Data was collected repeatedly after the interval of two days for four months of summer from 8:00am to 5:00pm. The following equations were adopted to calculate the parameters of PV modules.

Maximum Power:

$$Pm = Im \times Vm \qquad (1)$$

Module efficiency:

$$\eta mod = (Im \times Vm / E \times A) \times 100 \qquad (2)$$

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Performance ratio:

$$PR = (Pm / Pm\ (STC)) / (G/1000) \qquad (3)$$

Direct solar irradiance:

$$EH = ED \times \cos\delta \qquad (4)$$

The PR shows the performance of modules observed at actual operating conditions compared to their performance at STC.

Table 1shows physical dimensions, electrical data and measured values of photovoltaic module.

Module dimension	76.9in (1954mm) ×
Cell dimension	156mm x156mm
No. of cells (in series)	72 (6 x 12)
Nominal Maximum Power	295W
Optimum Operating Voltage	36.0V
Optimum Operating Current	8.19A
Open Circuit Voltage (Voc)	44.5V
Short Circuit (Isc)	8.76A
Module Efficiency	15.37%
Temperature	-0.43%/ °C
Temperature Coefficient(Voc)	-0.34 %/°C
Temperature Coefficient(Isc)	0.065 %/°C

V. RESULTS AND DISCUSSION

Data was collected repeatedly after the interval of two days for four months of summer. As the month of August (moon soon) in Pakistan is reportedly known for rain, therefore the data was accounted for cloudy days and a distinguishable difference in power output was observed due to low irradiance. But the data were considered as a whole for four months. Figure 3 shows the variation of hourly average solar irradiance with respect to time. The four summer month's hourly average global radiation was found maximum 1005.3W/m^2 at 12:00pm when sun shines brightly.

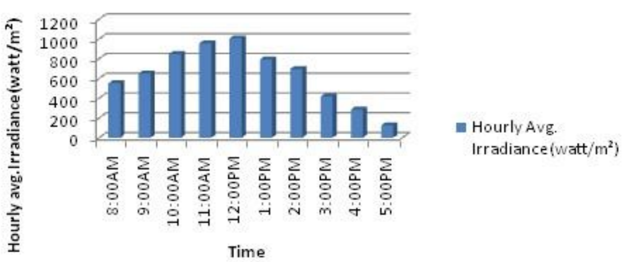

Figure 3 shows inconsistency of solar radiations with respect to time.

The power output of PV module rises with goes up of global solar irradiance. Linear relationship between solar irradiance and power output was observed. During the peak hours of sunshine, there is a greater solar irradiance and as a consequence power output is larger at this time span. It was recorded highest 192.32W at 12:00pm

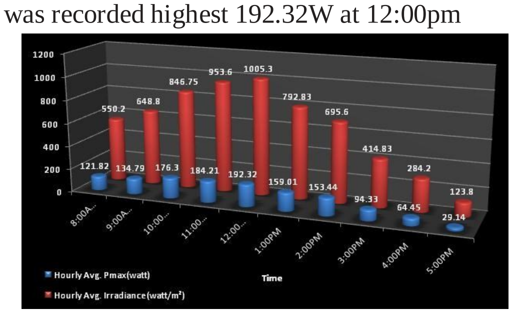

Figure 4, evident of the above mentioned scenario.

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Module's temperature plays a vital role in determining its efficiency. Module temperature increases when solar irradiance is greater and also has relation with ambient temperature. The module temperature was high than the ambient temperature. The reason is that heat produces during conversion or photovoltaic process. Temperature is also a key component in determining the efficiency of PV module. Figure 5 shows how the power provided by the module varies with respect to ambient temperature. At the start of day, at 8:00am the ambient temperature is lower and as a result module's power output is higher. At 12:00pm, when the sun shines brightly the ambient temperature is higher and this results in decrease of output power. At afternoon when the solar radiance decreases, power output decreases as a result. This is clear from figure 5

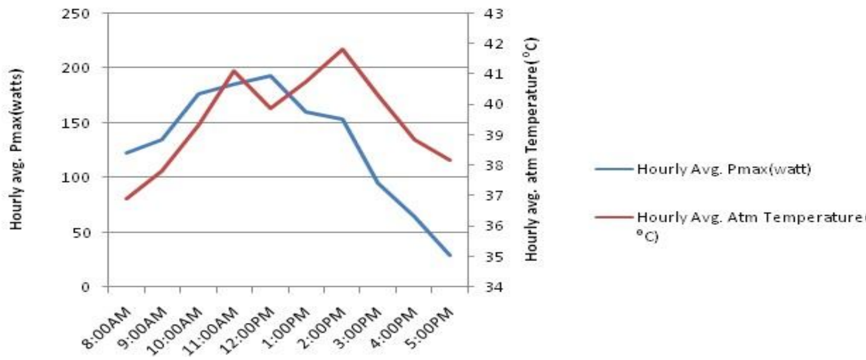

Figure 5, shows the behaviour between power output and atmospheric temperature.

Temperature is recorded from the back side of module affecting performance of module. Power output goes on decreasing when the temperature of module increases. Power output increases linearly with the increase of temperature but lost this linear trend at higher temperature. The fact is the decreased V_{OC} at high module temperature as stated by S.M.Sze.

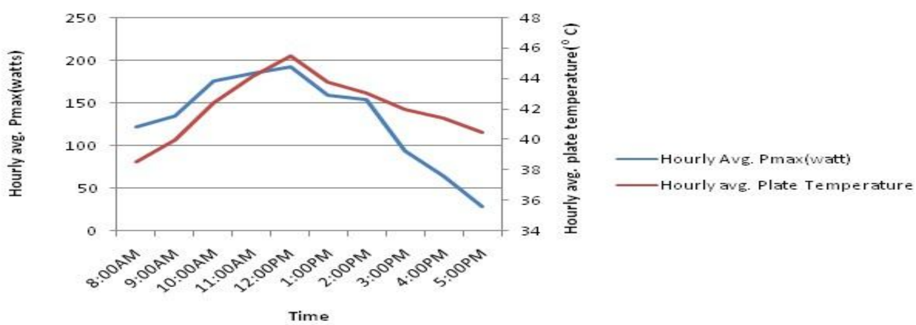

Figure 6, depicting the decrease of output power with the increase of plate temperature.

The efficiency of photovoltaic module decreases when there is increase of plate temperature as in figure 7.At the start of the day when temperature is lower the efficiency is better but with the increase of temperature it goes to decreasing. At highest temperature of 45.50 °C lowest efficiency 11.4% was examined.

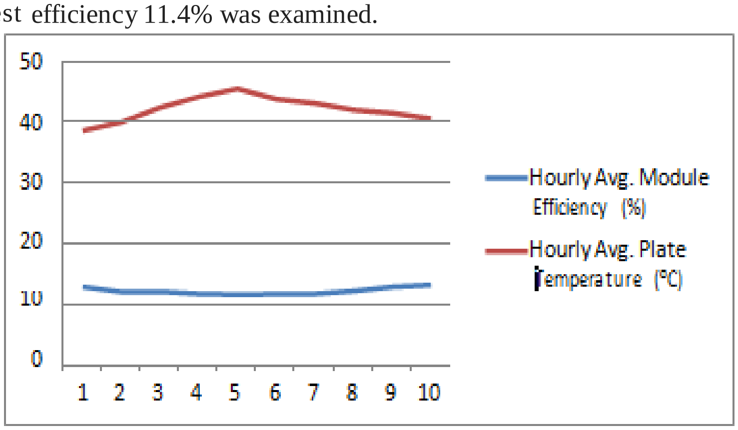

Figure 7 shows decreasing trend of efficiency as plate temperature increases.

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The efficiency of module is also a function of global solar irradiance. The PV module tested at al fresco conditions gives different output parameters due to changing outdoor conditions. The relationship between hourly average module efficiency and global solar irradiance is shown in figure 8. The lowest efficiency 11.4% was at 12:00pm parallel to highest global solar radiation of 1005.3W/m^2.As in figure 8.

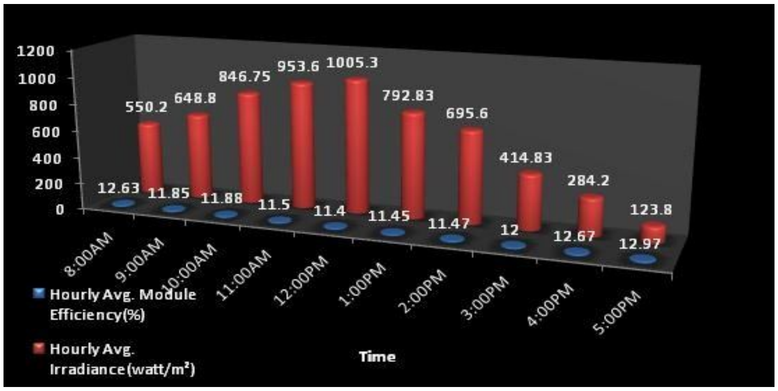

Figure 8 shows behavior of irradiance and efficiency.

Performance ratio compares the output parameters of module observed at actual/outdoor conditions with that performed at STC. It was observed a decreasing trend in PR as the plate temperature increases. The reason is increased global solar irradiance which causes the module to be heated and thus increase its temperature Figure 9 shows that during peak solar hour's from 11:00am to 2:00pm the hourly average temperature is highest that causes the module's PR to be lowered.

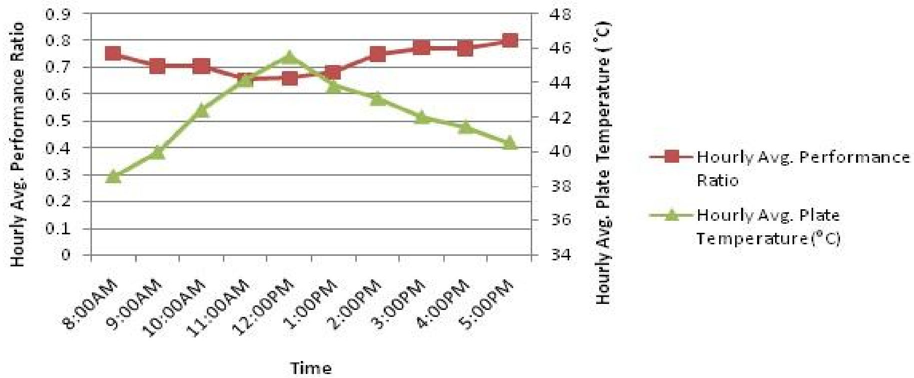

Figure 9, represents PR is lowest at highest plate temperature

Figure 10, represents the outcome of solar irradiance on PR. For summer months global solar irradiance was measured highest at 12:00 pm and at this point the performance ratio of module recorded lowest. After the hour angle of 30° (at 2:00pm) solar irradiance goes on decreasing and this leads the performance ratio to improve a bit.

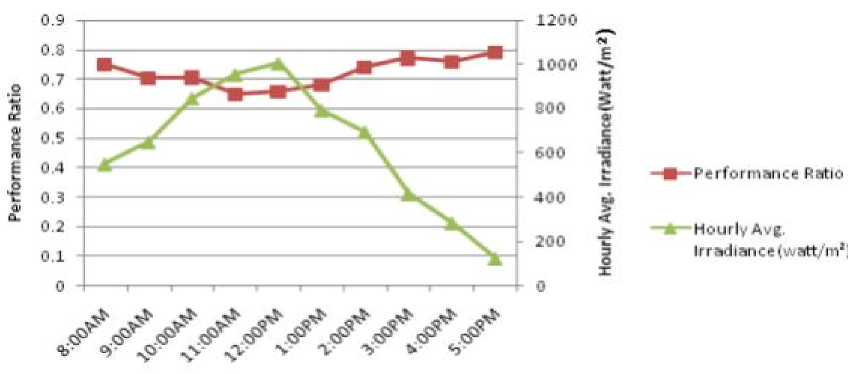

Figure 10 showing the fashion of PR with global solar irradiance.

VI. CONCLUSION

The major purpose of this study was to find out power output, module efficiency and performance ratio and to scrutinize the effect of global solar irradiance and back surface temperature of module on these parameters. After the whole experimentation, we concluded that there is linear relationship between solar irradiance and power output. At maximum global solar radiations1005.3W/m2 the power output is maximum 192.32W. Efficiency going to decrease with the raise of solar radiations. The increased PV unit temperature causes the power output to diminish. Lowest module efficiency 11.4% at 45.50°C was examined. Hence both higher solar irradiance and temperature at back surface causing module efficiency and performance ratio (PR) to be lowered.

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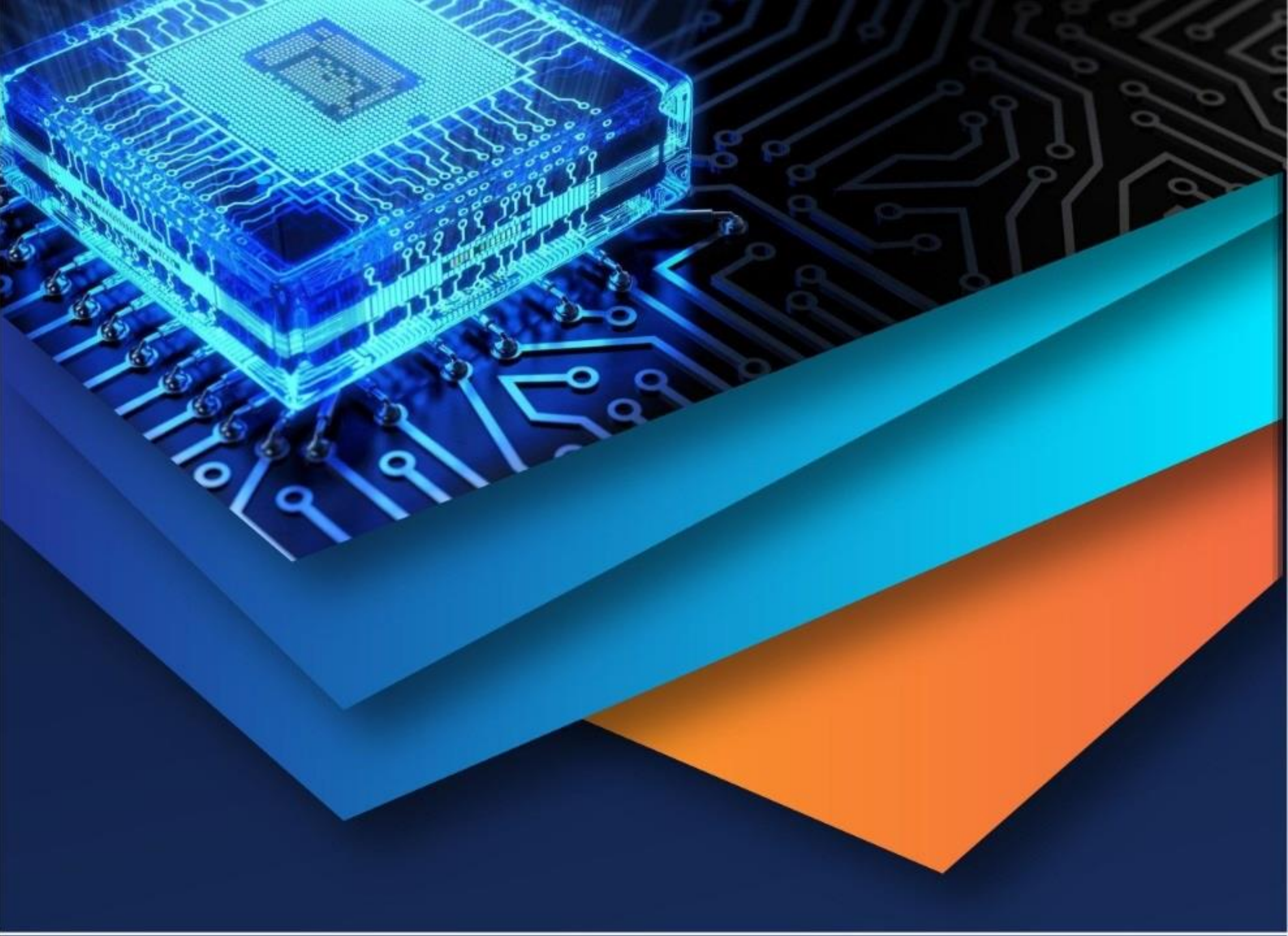

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