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Solar Radiation Prediction in India by using an ANN Technique

J. V. V. Sairam[1], A. V. Srinivasa Rao[2]
[1, 2]*EEE Department, Sasi Institute of Technology & Engineering, Tadepalligudem, AP, India*

Abstract: ***The paper examines the pattern of solar radiation in an altered purpose sequence and approximation the fault for every task. The revision targets forecasting the extreme solar energy generation per month in India, the pattern of solar radiation energy with sunlight hours, and the month with the highest solar energy radiation. The ANN method is used to predict solar radiation. The Artificial Neural Network (ANN) proper tool is used for the forecast of solar insolation. Solar insolation(radiation) information from 12 Indian stations with diverse climatic situations is used for instruction and test the ANN. The LM algorithm is used in this examination. The outcome of ANN representation is compared with calculated information based on MBE and RMSE. It is initiate that root mean square error (RMSE) in the ANN method vary 0.0486–3.562 for the Indian region.***
Keywords: Solar Radiation, Artificial Neural Network (ANN), Levenberg-Marquard (LM) algorithm, RMSE, MBE, Sunshine Hour.

I. THEORETICAL BACKGROUND

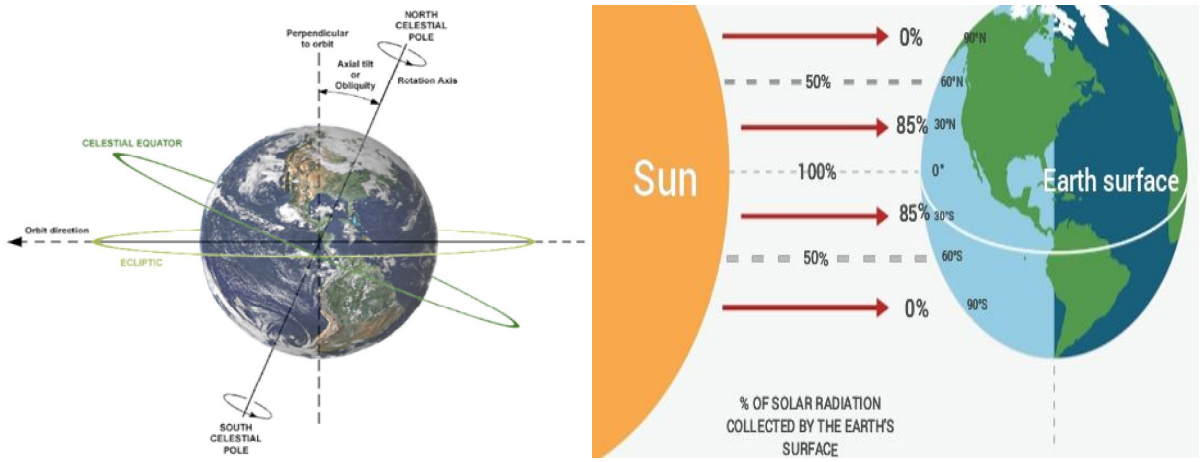

Fig. 1.0: (a) The level of the ecliptic is clear by the path of Earth around the sun. (b) The fraction of entering solar radiation (insolation) outstanding several latitudes throughout an equinox date allowing Lambert's Law.

Towards the accepting sun earth's relations be able to lead to the learning of deviation of solar radiation conventional from place to place during the year and into an inspection of the seasonal change on Earth. The seasonal distinctions in atmospheric turbidity, comparative humidity, wind speed, temperature, cloud cover, sunshine hour, pressure, and so on, mainly cause variation of the solar radiation established. In the same way, deep cloud envelops as well checks solar radiation from attainment earth's surface than in a pure sky. Though cloud envelop is uneven and unbalanced, and its cause is in a negligible amount more long periods. Though, two main phenomena that be different commonly for a particular place on Earth as it rotates on its alignment and rotates around the sun are (a) the period of daytime and (b) the direction of the solar emission. The quantity of daytime reins the extent of solar radiation, and the direction of the sun's emission in a straight line moves the intensity of the solar radiation expected. Mutually, the factor is the main influence that changes the sum of radiation presented at any position on Earth's surface.

In the Northern Hemisphere, Earth is nearby to the sun in the period and furthest away in another period. The direction at which the sun's emission incursion Earth's surface defines the quantity of solar energy expected per unit of surface area. This quantity in rotation interrupts the seasons. In the same way, in the Southern Hemisphere, the sun's emission is extra tilted and extent above larger areas, thus getting less energy per unit of the region when the Northern hemisphere expected the highest radiation and vice versa when it approves the least radiation which differs from the period of the year.

The latitude at which the noontime sun is overtly exceeding is known as the sun's declination. Ignoring for the instant the inspiration of the atmosphere on variants in insolation during 24 hours, the quantity of energy established by the plane begins behind daylight and rises as Earth rotates near the instant of solar noontime. A position will obtain its highest radiation at solar noontime when the sun has extended its top, or maximum position in the sky, for that day of the week. The quantity of radiation then losses as the sun's direction lowers near the next stage of dimness. clearly, at any position, no radiation is usual during the dark hours. Though, the quantity of everyday radiation expected at any one position on Earth varies with latitude. The seasonal borders of the main express radiation are used to decide the familiar zone on Earth.

Although different patterns in the entire radiation are expected in these zones, we can create various simplifications. For example, whole yearly radiation at the zenith of the environment over exact latitude left overs nearly stable from year to year (the solar stable). Moreover, yearly radiation tends to reduce from smaller latitudes to upper latitudes (Lambert's Law collected with Beer's Law). The nearer to the poles a position is situated, the larger will be its seasonal variations caused by variations in radiation. Study having to go on the calculation of the yearly insolation expected in a year and the next segment preceding works on the purpose of an algorithm for predicting solar insolation in a vacant position.

II. PRESENT KNOWLEDGE AND GOAL OF EXISTING WORK :

Arriving solar insolation has to be converted into important in many areas such as its effect on the energy and water stability at the earth's plane, soil heating, and air, photosynthesis, topography, meteorological limitations, agronomy, snow dissolve, evapotranspiration, winds, and others. Pollution, Gases, Vapors (as well as aerosol), and additional factors reduce this presented solar energy expected by the earth, and thus, the earth gets regarding 800 times less solar energy from the Sun at every second. It represents that the reduction in the whole solar insolation expected is partial by several factors the fraction of sunlight and the atmospheric turbidity feature are the major features disturbing the superficial solar radiation decrease. There is no correspondence relating to cloud and earth solar radiation. Though, the fraction of sunshine is precious mostly by cloud protection and air pollution.

Solar energy former proved to be a final and consistent resource of energy to complete the mainly essential electricity requirements during photovoltaic technology and since of its endless and non-polluting character. Several researchers universal have seen the consumption of enormous and plentiful solar energy resources on the earth's plane for electricity creation as one of the ways to gather the world increasing energy demand as well as to moderate the global warming effect that results from extreme confidence in the fossil fuel.

Research shows that sum of solar radiation established different from position to position and from month to month. Information of regular (or monthly) and longitudinal sharing of solar energy is essential for accurate energy arrangement and to accomplish the finest efficiency from on the whole electrical/ thermal system. Long-term information of obtainable solar radiation information in a particular place is important in the design and predict energy production of solar edition system, this information is finest found from measurements taken distantly at a particular place using several solar insolations gaging instruments. But unpaid to the high rate of calibration and keep of these instruments, solar insolation information is narrow in various meteorological stations around the earth and obtainable just in a small number of places in the country.

The solar insolation information should be considered always and exactly procedures over the long term. Regrettably, solar insolation measurements are not simply obtainable due to economic, technological, or formal restrictions. Solar insolation modeling has been used in rural and wooded areas. As such different empirical models have been used to forecast monthly mean daily solar insolation all over the earth.

The ANN is used to resolve several scientific evils. It can estimate any unremitting non-linear purpose to arbitrary accurateness. A multi-layer feed-forward neural system can approximate unremitting purposes due to its toughness, comparable design, and fault forbearance ability. In long-ago days, ANN models are used by several researchers to estimate solar insolation, and finished that ANN representation is confirmed to be better for further empirical deterioration model.

In the current lessons, an ANN model is developed which can be used to forecast solar insolation at any given position in India.

III. ANNS FOR SOLAR INSOLATION PREDICTION

Based on Haykin, a neural network is an extremely parallel-dispersed method or that can store empirical information and creation it obtainable for apply. It works like the individual brain in two complements: the network throughout a knowledge practice obtain the information, and inter-neuron relation strength recognized as synaptic weights are used to accumulate the information. ANN can hold a huge and composite system with several inter-connected parameters. It ignores irrelevant surplus information and concentrates on the extra significant inputs.

The mainly accepted and prevailing erudition algorithms in a neural network are the reverse broadcast. This algorithm is base on the fault-rectification erudition law. The fault reverse-broadcast procedure consists of an advance exceed and a rearward exceeds. In the advance exceed, input vectors are useful to the input film of the network, and its cause propagate throughout the network via link weights and film by film. lastly, a set of output is formed as the real reaction of the network. Throughout the advance exceed, the synaptic weights of the system are set whereas throughout the rearward exceed, the synaptic weights of the system are all familiar in agreement with the fault-rectification law. The real reaction of the system is to subtract from the preferred (goal) reply to create a fault indication. This fault indication is then propagated rearward during the system.

This system consists of an input film, an output film, and regularly one or extra unseen layer. The construction used in this job has an input film off our inputs, one unseen film with a tan-sigmoid creation purpose f, defined by the logistic purpose as $\phi = \frac{1}{1+e^{-n}}$ where n is the related input. For the output film, a linear creation purpose 'Purelin' is used. The MATLAB nftool (Neural Network Fitting Toolbox) is used for the execution. The algorithm 'TRAINLM' is used for the preparation of the system.

IV. METEOROLOGICAL INFORMATION AND METHODOLOGY :

In the current study 12 Indian positions, Vishakapatnam, Mangalore , Kolkata, Mumbai, New Delhi, Nagpur, Shillong, Jodhpur, Dehradun, Chandigarh, Ahmedabad, Lucknow are chosen. The meteorological information is calculated by IMD (India Meteorological Department) and compiled. Monthly mean solar insolation on a flat plane; meantime sunbeams per hour, elevation over sea stage for these positions, are used.

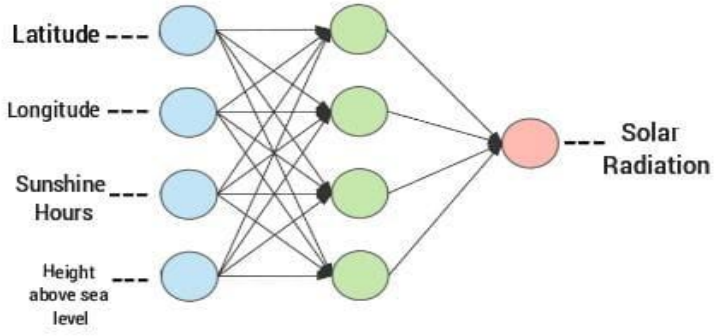

Fig 2.0: Prediction of solar radiation by using ANN architecture

A computer program has been performed in MATLAB with nftool (Neural Network Fitting Toolbox). The geological and sunbeams hour information for the city Kolkata,Mumbai, Chandigarh, Lucknow, Dehradun, Mangalore, Ahmedabad, Jodhpur are used for training information and the geological and sunbeams hour information for city Shillong, Vishakapatnam, NewDelhi, Nagpur uses for the testing.

Table.1.0.Geological features of Stations in India

Stations	Latitude (°N)	Longitude (°E)	Height above sea level (m)
Vishakapatnam	17.72	83.23	3
Mangalore	12.95	77.63	897
Kolkata	22.65	88.45	6
Mumbai	19.12	72.85	14
New Delhi	28.58	77.2	216
Nagpur	21.15	79.12	311
Shillong	25.57	91.88	1598
Jodhpur	26.3	73.02	224
Dehradun	30.31	78.03	683
Chandigarh	30.73	76.88	347
Ahmedabad	23.07	72.63	169
Lucknow	26.75	80.88	128

The statistical models like

Sum of square error (SSE) :

$$\sum_{i=1}^{n}\left(SR_{i(ANN)}-SR_{i(actual)}\right)^{2}$$

Absolute fraction of variance :

$$\left(1-\left(\frac{\sum_{i=1}^{n}\left|SR_{i(ANN)}-SR_{i(actual)}\right|^{2}}{\sum_{i=1}^{n}SR_{i(actual)}}\right)\right)\times 100$$

Mean absolute percentage error(MAPE) :

$$\left(\frac{1}{n}\sum_{i=1}^{n}\left|\frac{SR_{i(ANN)}-SR_{i(actual)}}{SR_{i(actual)}}\right|\right)\times 100$$

Mean square error (MSE) :

$$\left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(SR_{i(ANN)}-SR_{i(actual)}\right)^{2}$$

are correspondingly where n is the number of inputs models, $SR_{i(ANN)}$ is predicted solar insolation by ANN, $SR_{i(actual)}$ is real solar insolation.

V. RESULTS AND DISCUSSION

The performance plot is exposed in the figure 3.0. In this figure, MSE has to turn tiny by rising the number of epoch. The experiment set fault and the confirmation set fault have related uniqueness and no considerable over appropriate has occurred by epoch 6 (where the most evidence performance has occurred.

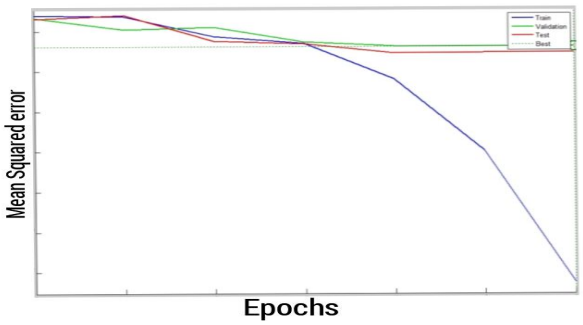

Fig 3.0:Performance plot

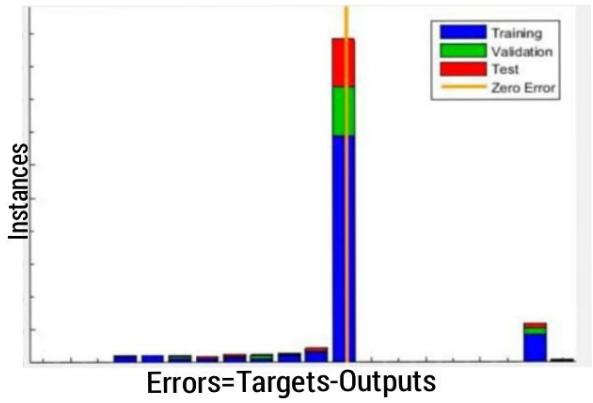

Fig 4.0:Error Histogram plot for Training information

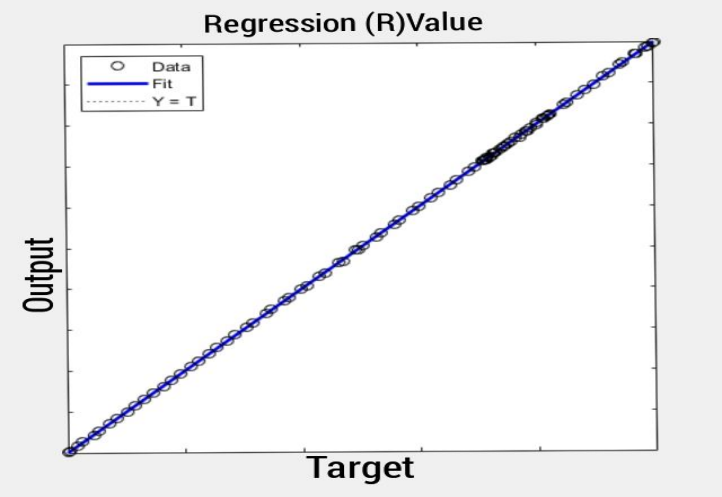

Fig 5.0: Regression Plot

Table.2.0. Error-values examination of ANN through training

Stations	MSE(%)	RMS	MAPE(%)	SSE	V^2 (%)
Lucknow	0.0502	0.2240	1.5699	0.6018	99.17
Jodhpur	0.066	0.2581	1.8822	0.7994	98.69
Ahmedabad	0.0277	0.1664	1.2803	0.3322	99.52
Dehradun	0.0132	0.1149	0.8998	0.1584	99.75
Mangalore	0.0531	0.2304	2.1462	0.6371	99
Chandigarh	0.015	0.118	0.887	0.1567	99
Mumbai	0.0024	0.0486	0.2783	0.0283	99.95
Kolkata	0.0337	0.1836	1.9896	0.4047	99.32

The error Histogram plot for training information is exposed in Fig 4.0. For extra confirmation of network concert. Mainly of the information fall on zero error row which provides a plan to confirm the outliers to verify if the information is terrible, or if those information points are dissimilar to the respite of the information.

The regression value (Rvalue) among the targets and outputs is a quantify of how healthy the disparity *in the outputs is explained by the targets. The b (intercept) and m (slope) values in Fig5.0,* which forecast the robust are fine. The regression value (R-value) for the whole reaction is exposed in Fig 5.0.

The predicted solar insolation value is secure to the real standards for every month. A tiny variation is experiential for the intended standards. The lowest and highest MAPE is 0.2783% and 2.1462% for Mumbai and Mangalore correspondingly. The lowest significance of absolute fraction of variance value is 98.69% for Jodhpur. The greatest significance of absolute fraction of variance value is 99.95% for Mumbai.

Table.3.0. Error-values examination of ANN through testing

Stations	RMSE
Vishakapatnam	1.7123
Nagpur	3.562
New Delhi	1.4610
Shillong	2.5469

VI. CONCLUSION

Prediction of solar insolation(radiation) utilizes diverse empirical models to approximate the monthly worldwide solar insolation is achievable by the utilize of the accessibility of plentiful sunlight in the country. The exploit of the ANN method in model solar emission(radiation or insolation), is reported. The revision indicates that chosen ANN representation has minor RMSE. This representation is urbanized by counting height above sea level, latitude, sunlight hours, and longitude of diverse states in India. An evaluation of the representation with the considered information exposed that the prediction of solar radiation (insolation) using this representation is in excellent conformity with the India Meteorological Department (IMD) considered information. As such the representation residential, is appropriate for forecast solar insolation for positions in India for which solar radiation (insolation) is compulsory for situate exact solar energy purposes particularly for solar power creation.

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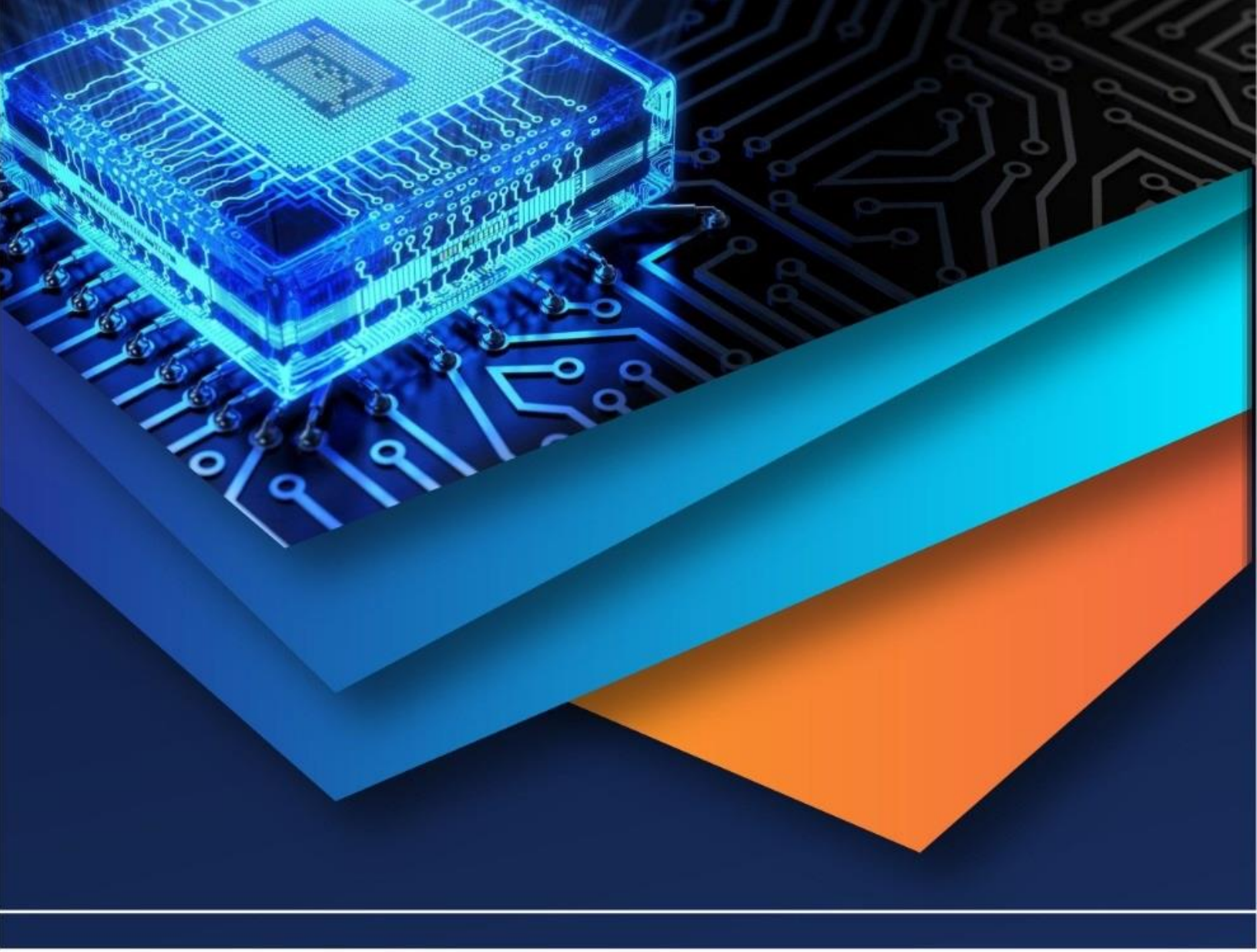

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