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A Review on Hybrid Microgrids

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***Abstract:** In the current scenario,the energy demand of domestic,commercial and industrial sector is increasing day by day,creating challenges and setting a limit on power generation using conventional energy sources[1]. The solution to this problem lies in shifting the power generation from conventional energy resources to renewable energy resources (RES)[2],which are more efficient,cost effective and reliable. To utilise the potential of RES properly, a systematic approach is taken which outlooks the generation and connected loads as a subsystem or a microgrid. However , the setback for this technology is that RES are intermittent in nature. In order to address this problem , a new approach of hybridisation of RES to back up each other is in use. In this paper, PV- battery microgrid, PV-hydro-battery-microgrid , PV-wind-battery microgrid have been elucidated .*
***Keywords:** microgrid (MG),microsources,Distributed generation (DG), photovoltaics(PV), Renewable Energy Sources (RES) ,Maximum Power Point Tracking (MPPT), Battery Energy Storage (BES).*

I. INTRODUCTION

Microgrid is a localized group of electricity sources and loads that normally operates connected to and synchronous with the traditional wide area synchronous grid (macrogrid), but can also disconnect to "island mode" — and function autonomously as physical or economic conditions dictate [3]. In this way, a microgrid can effectively integrate various sources of distributed generation (DG), especially Renewable Energy Sources (RES) - renewable electricity, and can supply emergency power, changing between island and connected modes. Microgrid also consist of energy storage systems e.g. batteries and energy generation sources like turbines and fuel cells can also be added to increase the reliability of the system. Multiple simulation tools and optimization tools [4] exist to model the economic and electric effects of Microgrids . A widely used economic optimization tool is the Distributed Energy Resources Customer Adoption Model (DER-CAM) from Lawrence Berkeley National Laboratory. Another frequently used commercial economic modelling tool is Homer Energy, originally designed by the National Renewable Energy Laboratory. There are also some power flow and electrical design tools guiding the Microgrid developers. The Pacific Northwest National Laboratory designed the public available GridLAB-D tool and the Electric Power Research Institute (EPRI) designed OpenDSS to simulate the distribution system (for Microgrids). A professional integrated DER-CAM and OpenDSS version is available via BankableEnergy . A European tool that can be used for electrical, cooling, heating, and process heat demand simulation is EnergyPLAN from the Aalborg University in Denmark.

II. PV-BATTERY-BASED MICROGRID

This microgrid consists of a combination of PV array with batteries and this ,in turn, is connected to utility grid. The solar PV array is made of modules , which are connected in series and in parallel. The generation of stable, maximum ,continuous energy from the PV array is achieved through MPPT technique. The simulation of microgrid should be done in such a way that supply from solar PV and the BES is preferred over utility grid.

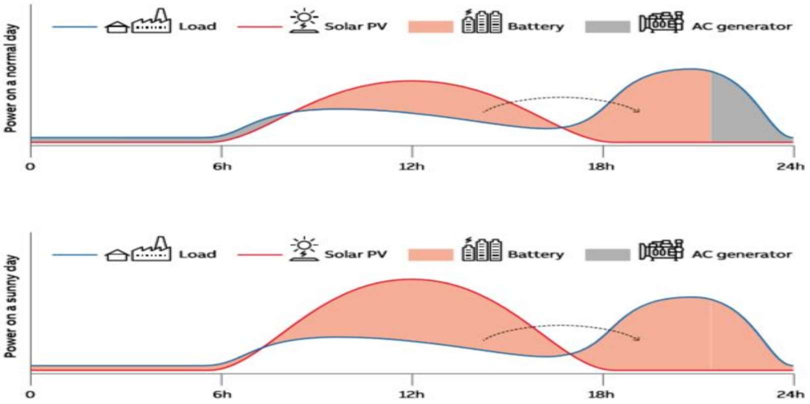

Fig. 1. Power consumption based on solar insolation [5]

III. ENERGY STORAGE SYSTEMS

A. Battery Energy Storage (BES)

The batteries used are for storage of renewable energy generated which is left unutilized at that time. Also , BES is used for supplying surplus power at peak load condition [6] Average discharge voltage of various batteries is shown in table 1 [7]:

TABLE 1. Average discharge voltage of 5 kind's battery

Battery type	Battery voltage/V	Explanation
Lead-acid battery	2.0	The most economical and practical
Nickel cadmium battery	1.2	Memory function
Ni-MH secondary battery	1.2	Sensitivity to temperature change
Lithium ion battery	3.4	Safety ,No lithium metal
Lithium polymer battery	3.0	Lithium metal

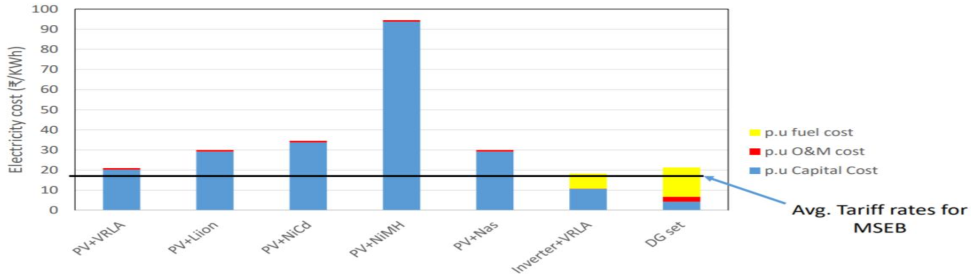

Fig.2. cost analysis of various grid back up systems [8]

Energy storage systems consist of flywheel, lithium battery, fuel cell, hydrogen storage batteries ,etc.

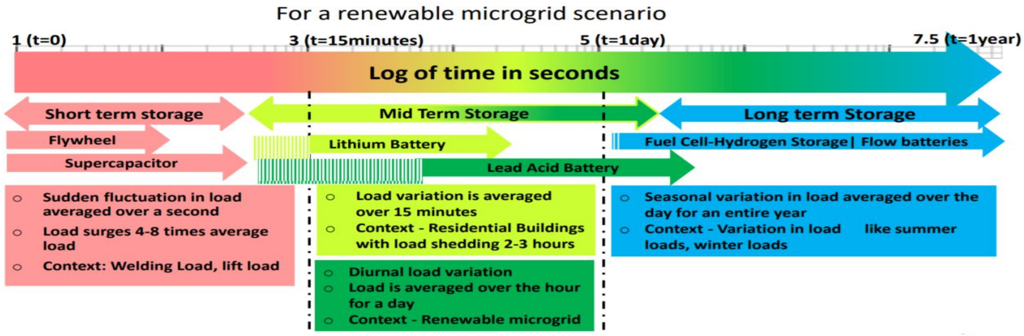

Fig.3. Classification of energy storage systems[8]

Application	Description
Load leveling / solar self-consumption	Stores power during low-load periods and delivers it during periods of high demand in order to reduce the load on less economical peak-generating facilities
Frequency regulation	Absorbs and injects active power in order to keep grid frequency within pre-set limits
Renewables firming	The energy storage system smooths the power output to eliminate rapid voltage and power swings on the electrical grid
Ramp rate control	Ability to limit the power ramps of solar or wind plants for reliable interconnection to the grid
Deferring T&D upgrades	Grid operators can place storage close to the load so it can discharge during peak system periods, reducing stress on the local equipment and instantly increasing capacity without large Transmission Distribution (T&D) investments
Peak shaving	Reduce power consumption during periods of high demand, which would reduce peak demand charges
Spinning reserve	Available power supply that can quickly respond to instant losses in generation or transmission outages
Back up	Provides power in case of blackout and/or grid outages
Power factor & voltage support	Provides reactive power compensation to regulate voltage to improve power quality
Seamless transition from grid mode connection to islanded connection	Meet the challenges for robust power supply in isolation from national grid infrastructure and gain control of your power needs on 'local' level

Fig .4. applications of energy storage systems[5]

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IV. ISOLATED RURAL WITH PV-BATTERY SYSTEM

The fig 5 shows an estimate of the load demand supplied by a PV-battery system.

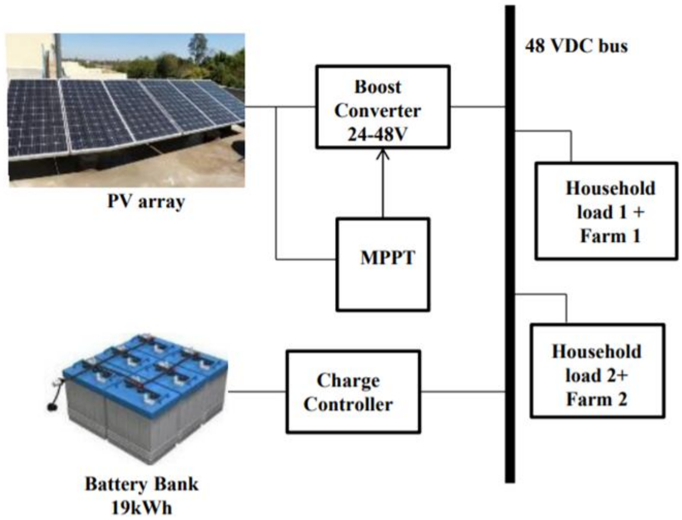

Fig.5. PV battery system[8]

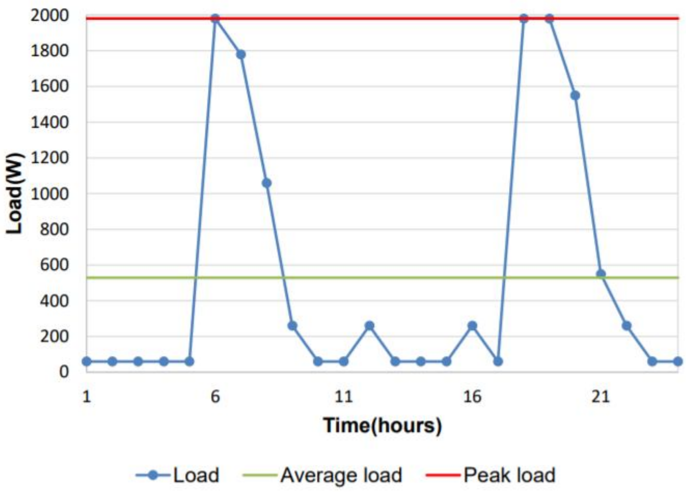

Fig.6. load demand of a rural area [8]

Table 2 demand and supply of solar power[8]

Energy Source	Solar PV – 4.3kW
Storage	Lead Acid battery – 19kWh
Connected Load	4.4 kW
Distribution Voltage	48V dc (Safety Voltage for distribution)

The system above shows how a PV array of 4.3 KW and battery bank of 19 KWh is used to supply a peak load of 2.0 KW.

V. PV-HYDRO-BASED HYBRID MICROGRID

As the name suggests, this system consists of PV-hydro batery hybrid microgrid. PV being of intermittent nature, post a problem to the optimal sizing [9] of the energy storage. The minimum required battery size, depends on the critical load that the MG must be proficient of serving when the solar energy is inaccessible. This makes the storage oversized. However , in the proposed MG, hydro too supports the critical load, so the battery size is reduced. Also, initial and operational expenses, are low and maintenance necessity is also less.[10] The small hydro power plants in distant regions is known as a favorable energy source to produce electricity. The small hydro system up to 100 kW rating does not require governor control based turbine prime mover and restricts down the cost of the turbine. The generator used in the small hydro has many variations [11-14]. Synchronous generator [11], permanent magnet synchronous generator [14], synchronous reluctance generator and self-excited induction generator (SEIG) [13,14], are some of them. However, the most cost effective, efficient, rugged, and easy to use generator in the small hydro system is SEIG. Also, the maintenance necessity is also less in comparison to its synchronous counterpart. SEIG has the drawback that it demands reactive power or magnetizing current for producing the desired terminal voltage. Therefore an excitation capacitor bank provides magnetizing current for regulating the terminal voltage of generator [15]. The hydro based generating system operates in almost constant power mode so that if the load changes the frequency and voltage also changes from their reference values. PV battery hydro based MG is used for low voltage and supplies power to small community of customers.
The proposed microgrid consists of 2 energy sources i.e. Hydro and PV with BES.

Benefits:
The proposed MG has the following distinctive features:

It adds stiffness and inertia to the system voltage and adds reliability to the system.

During the period of a load change, the controller estimates the load power demand and total generated power. If the load demand is more than the generated power, the controller draws the remaining power from the battery to balance the power demand. Similarly, for light load condition, the battery takes the extra power to maintain the frequency of the system.
The proposed MG mitigates the negative impacts of solar PV array caused by the intermittent nature of the solar irradiance. Due to this intermittency, the power generated by the solar PV array changes continuously. Therefore, the storage battery absorbs power fluctuations and maintains the frequency of the MG.
The simulation of the microgrid should be done in such a way that energy supply from PV –hydro-battery system is preferred over the utility grid ,thereby , decreasing the reliance on conventional energy resources.

For example; In Qinghai area, China, there is an isolated power grid in Yushu County[16]. In 2010, the grid is run by 2 hydro power stations with potential of 12.8MW, but the available power in dry season (from October to March) will reduce 50%. The peak demand in winter is 13MW and the peak time appears between 8:00pm-11:00pm. Therefore, a 2MW PV station with battery is prearranged in the power grid and shown in fig 7.

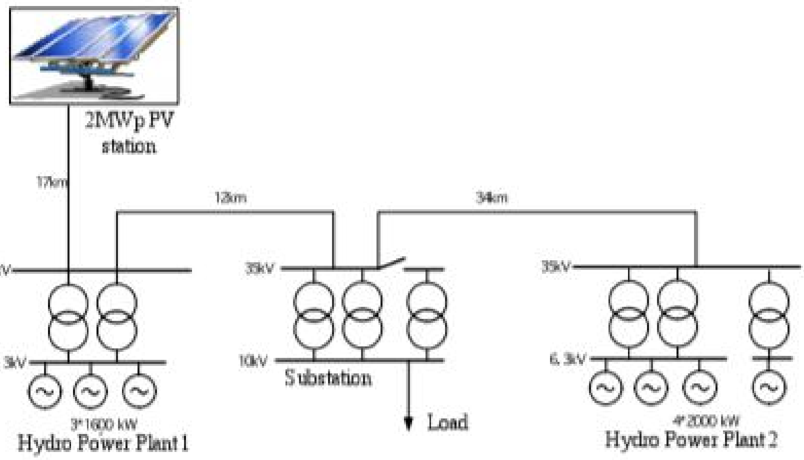

Fig.7 2 MW PV station with battery [16]

In designing a hydro/PV system, there are 4 main concerns including energy demand, peak power demand, battery lifetime and generation cost on kWh basis.

VI. PV-WIND BASED HYBRID MICROGRID

This microgrid comprises of PV-Wind-battery system. PV and wind are both intermittent sources so can be coupled with BES to increase the efficiency of the system.

Simple estimate of load shifting using microgrid:

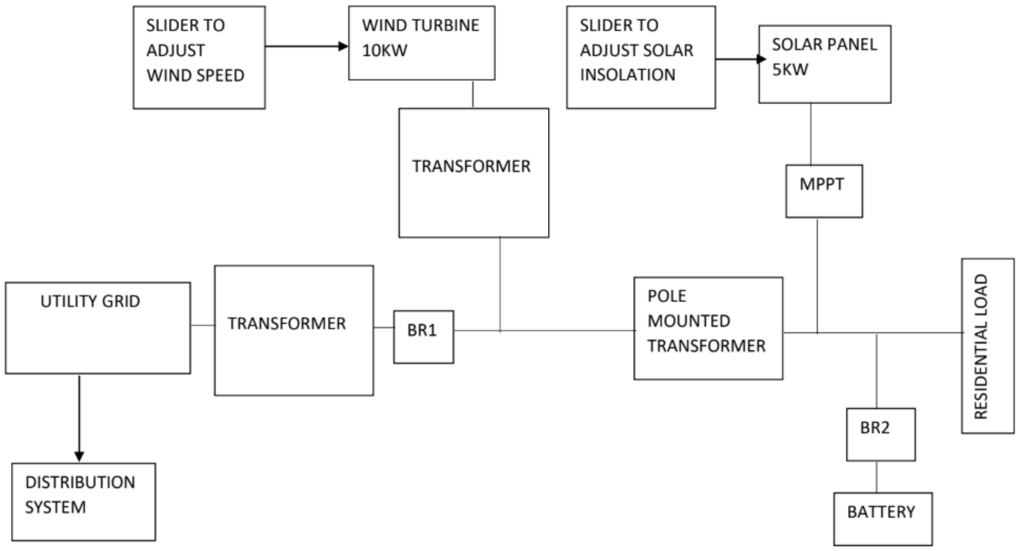

Fig .9. PV-wind based hybrid microgrid[17]

The fig.9 above shows the connection of wind turbine of 10 KW , solar panel of 5 KW and battery to the utility grid ,all being connected to the residential loads. BR1 , BR2 are the switches connected to utility grid and battery respectively .
<u>This microgrid works in 2 modes</u> i.e.

A. Mode 1 : Connected to Utility Grid i.e. BR1 closed [17].

1) Case 1 : Let us assume that the residential load is 13.85 KW
Adjusting the wind speed as 10 m/s using slider, the wind power generated is 7.08 KW .
Adjusting the solar insolation as 1000 W/m^2 , the solar power generated is 4.95 KW .
In such a case , the battery will supply the additional power required i.e. 2 KW (approx).
In this way , the total load demand of the residential area can be met using RES and inspite of being connected to the main grid , no supply is done via macrogrid.

2) Case 2 : Let us assume that the residential load is reduced to 6.71 KW.

Wind power = 7.08 KW
Solar power = 4.95 KW
Now, their combined generation exceeds than the residential load demand.
In such a case , the extra generation will be used to charge the battery .

3) Case 3 : Let us assume that the residential load increases to such a high value that microgrid sources are sufficient to meet the energy demands , in the case, the electricity will be supplied using combination of microgrid and utility grid.

B. Mode 2: Disconnected From The Utility Grid i.e. BR1 Opened.

In islanded mode, the microsources will keep supplying the residential loads to maintain continuity and thereby increasing the reliance and efficiency of the system.

VII. CHALLENGES

A. Current harmonics and unbalance;
B. Voltage fluctuation and flicker;
C. Poor frequency stability;
D. Transient voltage and current surge [6]

VIII. CONCLUSION

The above paper shows the combination of various microsources in a hybrid microgrid system and how the load shifting in them is desired. The above microgrid systems can be used as a boon to overpower the outages in the city. The backing up of one renewable source by the other also adds efficiency to the system , making them self-reliable. Microgrids, if become a reality , can be used to provide green and clean electricity and can prove to be a step ahead towards the goal of sustainable development.

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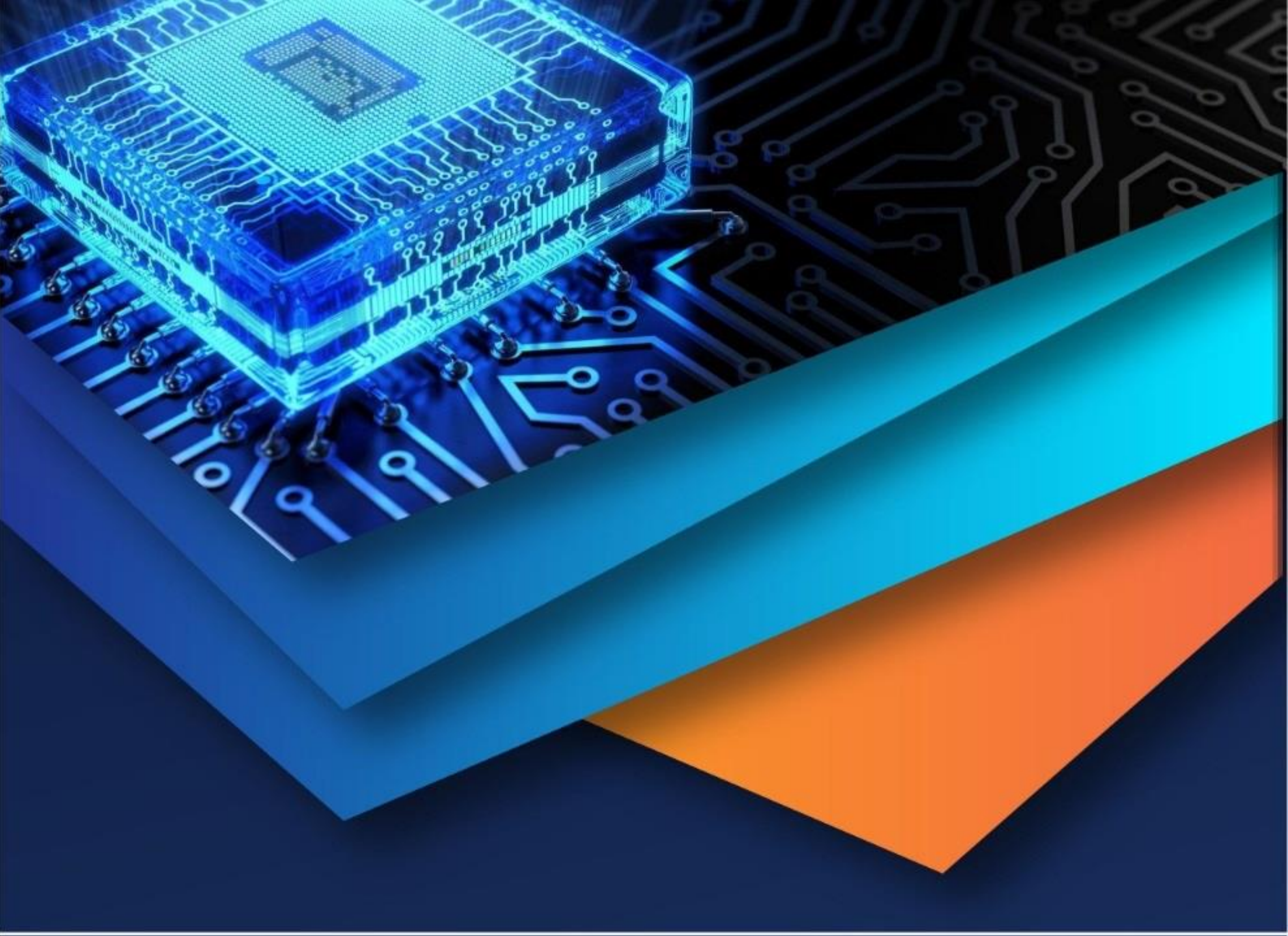

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