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Dynamic Power Management and Control of PV/PEM Fuel Cells based Standalone AC/DC Microgrid using Smart Prediction and Spray System

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Abstract:** In the todays world where the demand of the energy is growing an quicker speed for which the PV cells and systems are widely in use. So as to avoid the fluctuations in the growing demand of the power the solar systems can be well integrated with the power sources. Just because of the efficiency, modularity and flexibility the fuel cells are mostly used in such applications, and the major limitation in the case of the fuel cells are the low dynamics of the fuel cells. This work presents dynamic power management technique for AC/DC microgrids integrated with PV cells, PEM, and fuel cells (as alternate energy source). In the hybrid type of the power systems the fuel cells and the PV cells are used as major source of power generation. The power generated by the defined sources is well used for meeting the growing demand. At the time of the load transient the supercapacitor power banks are being used for the absorption and supply of the power. A specific controller is being used in the power for tracking the maximum power over the PV system, for the purpose of the power management the DC-DC boost converter with fuel cell controller is used in the system and at the same time the voltage and frequency are regulated by using inverter controller. The main goal of the stand-alone system is supply hassle free supply to user's for demand like residential and organizational keeping the voltage and current constant and also provides the facility of the power management using the defined controllers. The defined system is well implemented using the Simulink (MATLAB) and results are drawn as per the definition and requirements.

Keywords: AC/DC Microgrid; PV/PEM Fuel cell; Power Management; Energy; Current; Voltage.

I. INTRODUCTION

As of the current picture the present energy requirement the production is generally being done using the fossil fuels like water, which are depleting at quicker rate. The major goal is reserve the fossil fuels for future requirement and meet the current energy requirements going some alternate solutions for the energy generation. The usage of the fossil fuel for power generation also causes pollution to the environment by the emission of the various gasses as end outcome of the generation process. Just because of the above defined factors made to go for the alternate solution for power generation which can meet the current requirements and also to make the impact of power generation over environment less harmful. PV (Photovoltaic) cells are the p-n junction semiconductor devices which generates DC power from the sunlight.

The power generation using the PV cells is noise free and also less expensive as compared to the system working over fossil fuels. The power generation using the PV cells requires sunlight as primary source and the supply of the sunlight over earth is not constant for which other integrated modules are required to provide the continuous power supply. In the power generation the chemical energy is converted into the DC power or electrical energy.

As a alternate the wind energy is also been used for the power generation but the extraction can be done efficiently in the regions where the wind is blowing with required speed and also the installation cost for the wind power generation plant is quite high as compared to that of the solar power plant. The reliability of the battery usage as power storage system is quite low for which the fuel cells are most considered alternate solution. In most of cases when the cells are having fuels with they generate DC energy of about 60% of the total [1].

II. MODELLING OF HYBRID POWER SYSTEM

The power generated using the renewable form sources like solar, wind water is having the power fluctuations for which the power backup system is required at most. For the purpose of the energy storage majorly batteries, hydrogen tanks, super-capacitors are used to provide the continuous energy supply or to match the supply requirement. So as to achieve the hassle free supply the components of the power system are supposed to be considered carefully and also the components should be managed using the specific controllers where ever it is required. The section below will cover the major components used in the hybrid system and the same is considered in the research methodology defined in the paper:

1) PV System.
2) Fuel cell System.
3) Batteries (or super-capacitor).
4) Power management system.

III. POWER MANAGEMENT STRATEGY

In the hybrid type of power system multiple sources are used for power generation like batteries, fuel cells and PV cells at different time interval, for which a specific protocol is required to supply the energy from the defined sources. In the case of the PV the energy generation highly depends on the weather conditions and in many of the cases the system generates more power than required which is supposed to be stored as backup power plan and the same can be used whenever it is required. For the purpose of the power management in HPS PI controllers are used so as to manage the load as per the requirement. For the management of the fuel cell systems a central controller is being used and PV system for DC-DC conversion as well as for DC-AC conversion.

DC output is generated from the end of the PV system, fuel cell and BESS, hence AC converter is being required for the conversion of the DC supply to the AC supply. In the initial phase the 3 phase voltage and current values are measured and are then converted to RMS and the same is then compared with the voltage of the references. The generated error is provided to the PI controller and then the same is converted back to the 3 phase voltage an current. The generated signals are feded with the pulse generator which actually is responsible for the generation of the pulse in the inverter circuit [2]. With reference to various aspects of the described domain, the present work provides the description about the AC/DC microgrid with self-power balancing capabilities. Several important details are provided in the section, like the basics of the modelling of hybrid power system is given in section II, power management strategy is mentioned in Section III, the basics about AC/DC microgrid are described in Section IV, various techniques for power management are described in the Section V, problem statement on the basis of the previous studies are replicated in Section VI, research methodology is presented in Section VII and further sections provides the description about the results generated and concludes the study.

IV. AC/DC MICRO GRID

The hybrid AC/DC microgrid is depicted in the fig.1 below as a cluster of the AC microgrids (ACMG) and DC microgrid (DCMG,

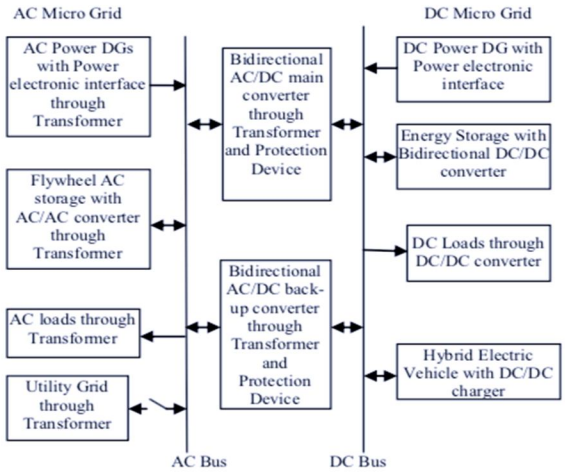

Fig.1 Basic Layout of Hybrid AC/DC Micro Grid.

Along with above described components the AC/DC microgrid is also equipped with bidirectional converters, control system, power management module. Diesel generators, small hydro turbine with synchronous generator, biomass based power generation etc., AC loads, fly wheel energy storage system with AC/AC interface and utility grid connection through bidirectional power electronic

based switch at the point of common coupling (PCC) are integrated in the ACMG of DGs with AC power output. photovoltaic panels, fuel cell tracks etc., loads requiring DC power input such as Uninterrupted Power Supply (UPS), fluorescents lighting etc., DC energy storage system (DCESS) such as battery, super-capacitor etc.,, and hybrid electric vehicles are included in the DC power output by the DCMG. With the help of DC/DC buck or boost converter, these components are able to connect with the DC bus. To interface ACMG and DCMG, a bidirectional AC-DC/DC converter is required. To avoid any islanding of ACMG and DCMG, there is a need of Back-up converter.[3] Between ACMG and DCMG there must be an smooth power transfer and there must be stability in the voltages of AC bus and DC bus with variable type of supply and demand of the energy and actually are the main requirements of the bidirectional AC/DC converter. In the case when the energy generation in the ACMG is more than that of the DCMG or just reverse for islanding different modes of operations, then the transfer of the energy s from ACMG towards DCMG [4].

V. LITERATURE REVIEW

A very best power management strategy among the assorted energy sources in HRES is important as a result of, the ability output from renewable sources is discontinuous and dependent on many uncontrolled conditions. The dynamic interaction between numerous energy sources, energy storage systems and masses, frequently needs an alert study of the transient response of the systems. The ability control strategy Ought to guarantee high system potency and high responsibility with least price. The most objective of the PMS ought to be providing the height demand in the slightest degree times. Within the hybrid systems, FC is future energy storage choice in demand and has multiple blessings [5-7]. However, the FC has some disadvantages like slow dynamics and dreadful conditions, as a result of repeated start-up and close up cycles. Thence batteries area unit used as short term energy storage systems in such hybrid systems to require care of power deficits. The mixture of FC and battery together with PV and Wind helps in making certain uninterrupted power provide to the load. The key parameters that influences the best power management strategy are summarized as follows: opportunity cost, budget items, time period and days of autonomy of storage devices (such as batteries and FCs), State of charge of storage devices or the force per unit area of chemical element tanks just incase of chemical element energy systems, the quantity of start- ups and close up cycles for banking industry and electrolyzer. The literature on power management strategy is kind of intensive and includes numerous configurations of the hybrid Systems involving PV, wind etc. Caisheng Wang et al. propose power management of ac-linked complete hybrid wind/PV/FC energy system [8-10].

Ipsakis et al. [11] Instructed 3 power management methods for a hybrid PV/Wind/FC/B Battery(B) system with chemical element production exploitation Electrolyzer. The ability control methods area unit compared supported a sensitivity analysis by considering some constraints like State of Charge of batteries and output power from cell. The vital call factors within the power control methods area unit the ability delivered by the renewable energy sources and therefore the State of Charge of the batteries. These PMS powerfully have an effect on the time period of assorted subsystems, principally the FC and Electrolyzer. The another study indicates that one dispatch Strategy cannot yield best results below dynamic operational Conditions and thence suggests a combined dispatch strategy [12-14].In a separate analysis, the authors analyzed a PV/FC/B hybrid system exploitation 3management methods, where by they ascertained the second control strategy to supply best hybrid system potency [15-17].

VI. PROBLEM STATEMENT

In the proposed methodology the work done by the R. K. Sharma et al.[18] is enhanced entitled as "*Dynamic Power Management and Control of PV PEM fuel Cell based Standalone AC/DC Microgrid Using Hybrid Energy Storage*". In this work author have proposed a dynamic power management technique for standalone AC/DC microgrids integrated with PV cells, PEM, and fuel cells (as alternate energy source).

In the proposed work the major problems that are considered are as under:

A. In the case when the continuous power backup plan is considered throughout the day, where the dust and pollution particles over the PV array is the major issue when dealing with solar power generation, as the arrays are installed in the outdoor part. The dust particles over the solar array just decreases the surface area availability of the solar array which results in the reduction in the power generation, for which a WLAN system will be used for automated spraying over the solar arrays when the dust particles reaches beyond the defined threshold of dust particles.

B. Smart power management plan, as the availability of power generation from the solar arrays is not defined means may degrade or be upgraded based on time/weather, for this a prediction system which is being trained on the basis of past supply and load records from the grid or to the grid are used. For better power backup and storage the hydrogen storage tank is being used which in the later phase will be converted into electrical energy using the electrolysers and power generators.

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VII. RESEARCH METHODOLOGY

The defined power management techniques produces current references for the available DC converters and controllers for current for fuel cells, battery and supercapacitor. The average filters are used for separating the fluctuating components. In the proposed methodology a power management scheme is considers which mapes the demand and supply and also ensures about the utilization of the available resources at most.

A. Main Components of the System

1) *Photovoltaic Array:* The PV effect is the common process where the sunlight is converted into electrical energy directly. The PV cell is similar to that of the p-n junction in terms of physics. In the solar array the solar radiance (Isc) and open circuit voltage (Voc) are directly proportional to one another. On the basis of above relation the higher power can be counted at the out end, temperature is also a major part in the overall conversion process. The power and open circuit voltage rises on lower temperature ranges.
2) *Fuel Cell:* In the PEM fuel cell the channel pressure is kept continuous and the input flow is kept uncontrolled inside the fuel cell. On the basis of the load current the input flow of the fuel cell is adjusted automatically and also the channel pressure is kept constant. The characteristic graph is drawn using three different areas. The aviation loss inside the fuel cell results in the voltage drop with respect to the low current, ohmic loss results in lowering of the current in middle over the stack, the load current rises at the end just because of the concentration losses.
3) *Electrolyser:* Electrolyser actually is a device used for the extraction of the hydrogen and oxygen content from the water. As inside the fuel cell the chemical reaction goes around for the conversion of the chemical energy into the electrical energy and for which the electrolyser is being used to convert the electrical energy from the extracted hydrogen. For the electrolyser of specific range the load current rises with higher DC voltage. Hence the hydrogen can be generated at greater level by applying the higher DC voltage to electrolyser.
4) *Spray System:* After the initialization of the system the data gathered from the dust sensor is fetched back and is checked for certain threshold if it matches then the pump or spray over the panel starts automatically and ends when the dust particles are less then the predefined threshold.
5) *Smart load Prediction System:* On the basis of the observation it is quite clear that the variations in the load are seen in the case when the power system is operating over the best available conditions. it can be concluded that the magnitude of the load variations depend on the system operating point.
6) *Boost Converter:* Single boost converter (or step-up converter) which is DC-to-DC power converter which increases voltage (meanwhile decreasing current) extracted its entered amount (provision) towards its received amount (load). It is actually class belonging to switched-medium power giver (SMPS) comprising even two semiconductors (one a diode , another a transistor) along with even single energy storage value: a inductor , capacitor either two merging up. For reducing voltage ripple, refiners comprising of capacitors (which are sometimes merged up along inductors) were normally combined towards this converter's resultant (load-side refinement) along with entry (supply-side refinement).
7) *Two directional DC-Dc Converter:* Single DC-to-DC converter which is electronic circuit either electromechanical equipment which changes single source belonging to direct current extracted unity voltage level towards other. This is kind considering electric power converter. Power levels lengthens extracted very down (little batteries) towards very top (top-voltage power transformation). Particular with given converters which is energy flows into both pavements of converter. Given converters were being utilized into many applications, they were attached among DC voltage two stages, in which energy is transformed extracting one level towards other.
   a) Augment Bidirectional DC into DC converter
   b) Contradict Bidirectional DC into DC converter
   c) Augment-contradict not-inverting Two directional DC into DC converter
   d) Boost-Buck upturning Two directional DC into DC converter
   e) SEPIC Two directional DC into DC converter
   f) CUK Two directional DC into DC converter
8) *Supar Capacitor Pack:* Single super capacitor (SC), also known ultracapacitor, which is top-capacity capacitor along condenser value more greater comparing another capacitors, however along lower voltage constraints, that overpass space among rechargeable batteries , electrolytic capacitors . It probably saves ranging 10 till 100 times much energy every unit volume either mass as compare with electrolytic capacitors, could adhere , provide charge more brisker comparing batteries,

suffers various many charge along with discharge cycles comparing rechargeable batteries. Supercapacitors were utilized into applications needs various quick charge either discharge circuits, in spite comparing long time compact energy storage — into cranes ,trains, buses, automobiles, elevators when they were utilized in order to again generative braking, small-term energy storage, either burst-medium power provision. Little units were utilized power backup in order to fixed random-access memory (SRAM).

B. Proposed Architecture

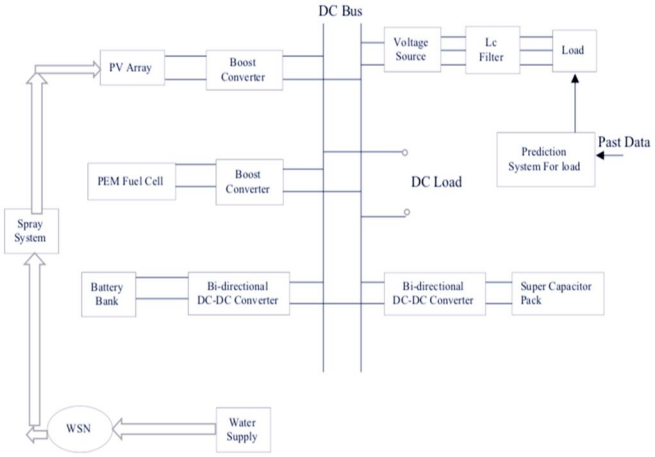

Fig. 2 Hybrid AC/DC Microgrid configuration with Spray system and Prediction system.

In the proposed methodology two new modules are added as prediction system and spray system, where the spray system works for ensuring the continuous availability of solar arrays to the photo voltaic cell so that the conversion is not affected, and the load and supply ratio can be properly managed. The PV arrays are installed in open environment where the dust, moister and other related particles are mounted over the cells via air, which actually reduces the available surface area for sunlight. In the proposed methodology a spray system is being used which works with WSN network in way that whenever the dust particles or the moister over the solar plates is more than the threshold value then it starts operation and sprays water over the solar plates to remove the dust particles. The complete module added increases the power generation and complete utilization of the sunlight and resources used in the process.

The next module added to the proposed methodology is prediction system which actually works as the power management process for the grid. The major concern to manage the demand and power supply ratio in a managed manner, hence in the proposed methodology the smart prediction system is used which works using the past data of all around the year and predict the demand for the current time using the past records. The complete process actually enhances the management of the demand and supply ratio.

VIII. RESULTS AND DISCUSSION

In the below segment the implementation results of the proposed work on the basis of hybrid AC/DC microgrid based on configuration 1 so as to validate the work presented and also to present the dynamic technique,. All the components are modelled in Matlab/Simulink in simpowersystem domain. In the study the ideal current and voltage demand is considered and also is compared with the supply voltage and current. The methodology uses the spray system for increasing the surface area availability to increase the supply voltage and current, the system also uses the variable DC sources as reservoir for backup purposes and also adjust the demand and supply ratio as per the requirements.

With t=0 to t=4 s, the system is works in Mode II, Condition F as the PV power is lower to load power. The deficit power is provided from the fuel cell, battery and SC. At t= 2 s, PV power deviates from 6.4 kW to 7.4 kW while at t= 4 s, load power degrades from 7.6 kW to 5.5 kW. Now, the hybrid microgrid operates in Mode I Condition A. At the same time, FC power start diminising while SC and battery absorb power to maintain dc link voltage. The system is attached with a spray system which works when the dust and pollution particles over the solar array rises above and predefined threshold, and system works for 30 seconds. In the below presented snaps the implementation generated outcomes are shown like variations in the load and supply using the proposed technique and also provides the comparison of variation in the voltage and current from different modules after and before the using the spray system.

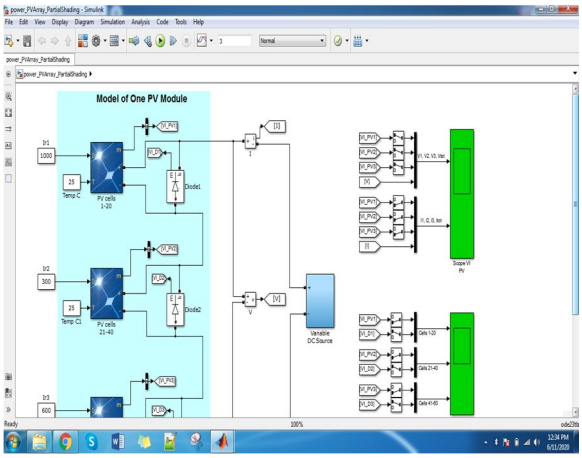

Fig. 3 Snapshot 1.

The figure 3 above are all about the working circuit diagram of the proposed methodology with connected spray system and variable DC source. In the circuit diagram all of the connected components of the model are shown with clear picture about the flow of the PV characteristics.

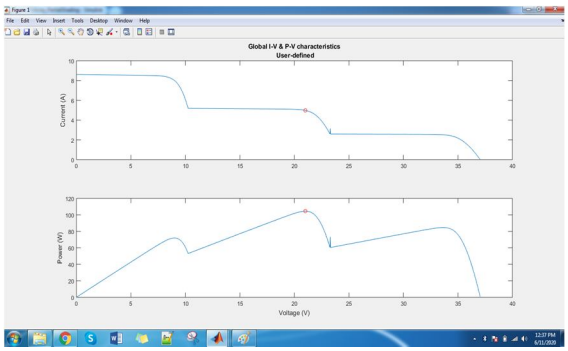

Fig. 4 Snapshot 2.

The figure 4 shows the ideal wave of the voltage and current requirements from the system as output with respect to the available working solar modules.

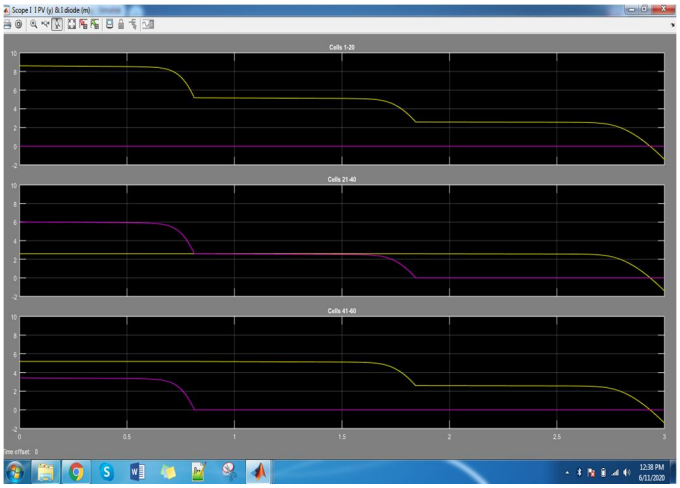

Fig. 5 Snapshot 3.

In the model 60 different cells are connected for the absorption of the solar energy and the is then converted into electric energy. The figure above shows the wave of voltage and current generated from different cells with respect to the demand and supply requirement of the same.

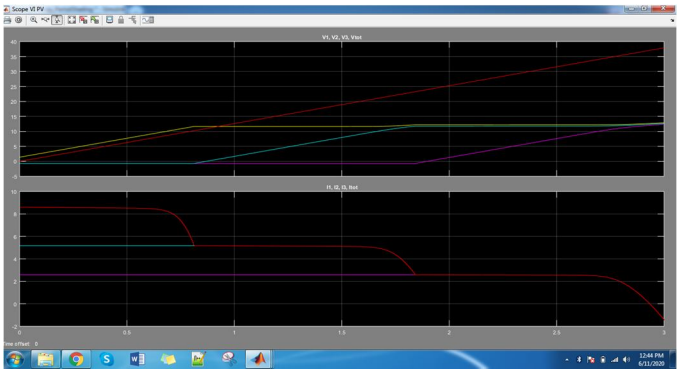

Fig. 6 Snapshot 4.

In the figure above three different variations of the voltage and current are considered and also shows the total voltage and current generated. From the output graph generated it can be clearly seen that there is a difference in the voltage and current generated by the system module equipped with spray system and also it is clear that the variable DC source used minimizes the difference between the demand and supply of the PV parameters.

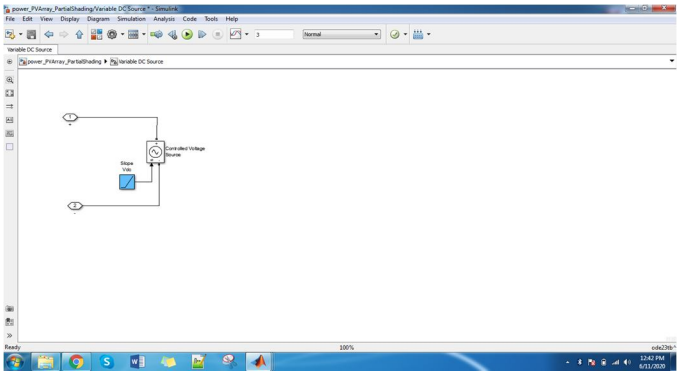

Fig. 7 Snapshot 5.

In the proposed methodology a specific module was considered to train the system just to minimize the demand and supply ratio on the basis of the past records of demand and supply. The variable DC source is used as backup plan when the solar modules are working in minimum state or capabilities.

IX. CONCLUSION

In this work, MATLAB/Simulink is being used for simulating the off-grid power system, considering different connections and integrated components. The work focuses on the mpact of the individual components and also of the complete system. The photovoltaic Panels, BESS and the fuel cell system are modelled individually using MATLAB 15. In the proposed methodology a specific module was considered to train the system just to minimize the demand and supply ratio on the basis of the past records of demand and supply. The variable DC source is used as backup plan when the solar modules are working in minimum state or capabilities.

As in the proposed methodology the existing system is enhanced using to modules as a spray system and a power backup system. The spray system is to remove the dust and pollution particles from the solar array assembled in the system, as the solar plates are always are affected by the environmental factors like dust, air, water, pollution and other. The spray system will work towards increasing the available surface area for the process of absorption of the solar light which directly affects the conversion process. In the complete WLAN system is also used which automates the process as in the case when the particles over the solar plates rises above or equal to the defined threshold value then the system starts spraying water automatically and works for 30 sec. In the second module the system is connected with a power back up plan in way to match the demand requirement, as the requirement changes on daily basis and also month wise and system should be trained to in a way that it automatically makes the system work according to the demand requirements. In the work the for power back a variable DC source is being used which works or supplies power in the case when the supply from the system is not sufficient.

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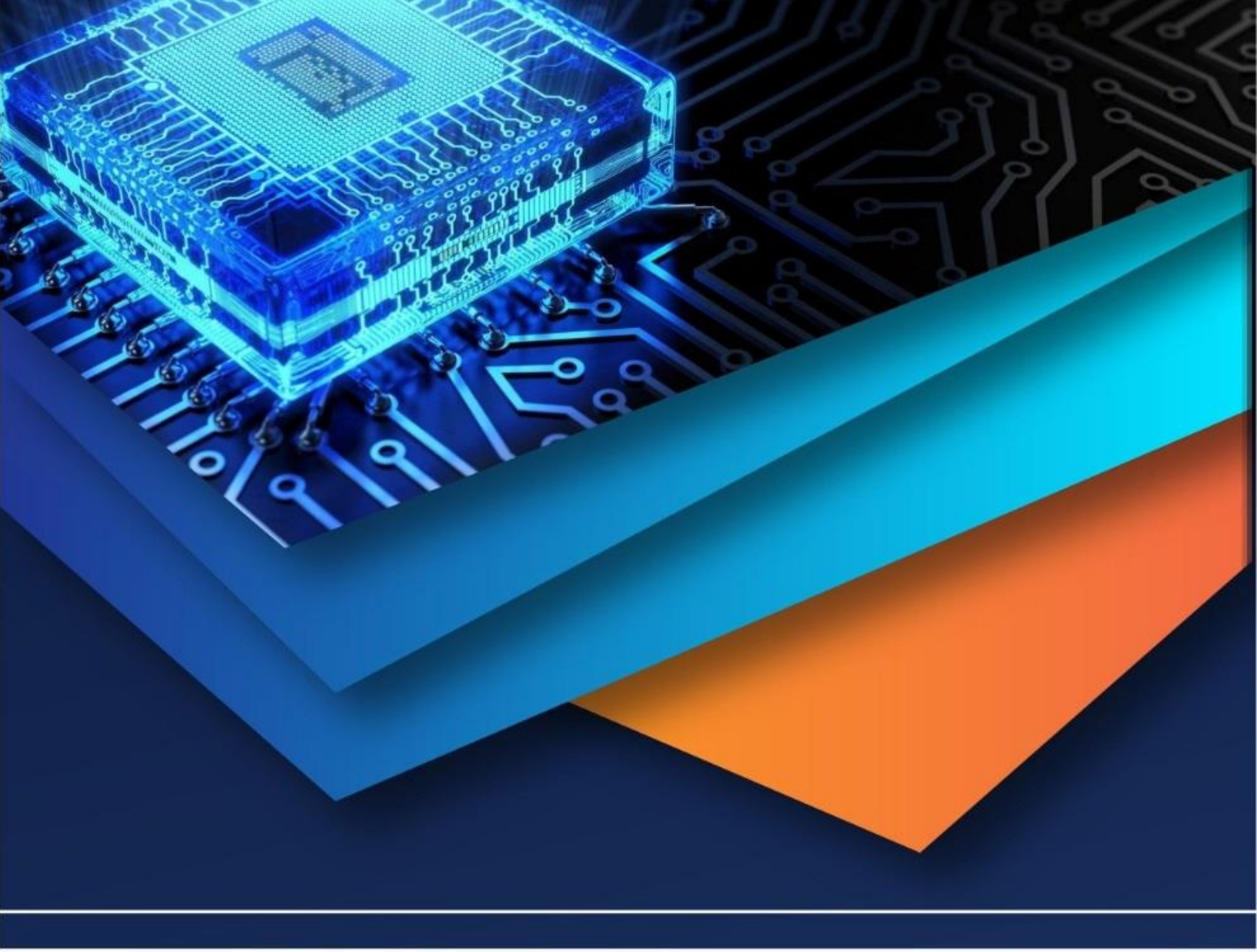

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