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A Review on the Performance of Aggregator of EV for Power Market

Pallavi M. Mankar[1], Yogita. D. Shahakar[2]
Assistant Professor, Electrical Engineering Department, PRPCE & M, Amravati, Maharashtra, India

Abstract: This paper presents a review on the performance of aggregator of EV for power market. The EV aggregator is defined as an interface entity that aggregates the EVs to act as dispersed energy resources, enabling them to support the V2G mechanism. There are various methods to optimize the performance of electric vehical aggregator for power market. This paper analyzes the bidding strategy problem of an aggregator managing a set of electric vehicles. The electric vehicle aggregator determines the bidding decisions in the market that minimize the charging costs of electric vehicles and, at the same time, meets the driving requirements of electric vehicle users. It will take into account the uncertainty in both market prices and driving needs using a set of scenarios, which allows formulating the problem using a stochastic programming approach. The impact of the bidding decisions of the electric vehicle aggregator on market prices is also addressed in the decision-making tool. A number of illustrative examples explain how to formulate and solve this type of problems.
Keywords: EV, Aggregator, V2G, G2V

I. INTRODUCTION

Significant changes have occurred all over the world even over the past decade in the energy landscape. Globally, there's a big push towards a 100% incorporation of wind and solar power for electricity production, with synergistic support from Vehicle to-Grid (V2G) technology. Large-scale electric vehicles (EVs) can perform as new channels of source and energy storage mechanism in the smart grid via implementing V2G intended for power injection from EVs to the grid. V2G awards EV owners with numerous innovative roles in the smart grid such as mobile energy storage, renewable energy storage, backup supply. V2G has been intended as a means of lessening the grid potential operational delinquents and enhancing the opportunity for the proliferation of EVs. There are however a host of challenges, most of which are due to the intermittency and unpredictability of the mobility behaviour and renewable energy resources (RESs), along with market price volatility. Therefore, V2G scheduling becomes emerging research focus with a large-scale application of EVs. Present market regulations restrict fair participation in power markets for individual EVs' G2V scheduling. The complete financial value of EVs would be realized provided policy outlines, market rules and regulatory reforms allow EV Aggregator (EVA) to provide multiple services (energy and ancillary services) simultaneously, addressing congestion at the system level, paying attention to satisfying reserve requirements, and serving to accomplish energy management for single EV owner. It enables EVA to ensure that EVs can receive fair remuneration for unlocking their multi-valued streams and providing flexibility services in a cost-competitive manner. If aggregated and controlled, EVs can provide flexibility to the system operator (SO). This thesis will focus on some of the possible solutions for the V2G integration for providing ancillary services that are control-centric. This thesis will cover some of these challenges to V2G scheduling, highlights the current research in V2G optimization, and use-case studies that illustrate the role of EVA in power grids and electricity markets. Smart V2G scheduling can reshape the load profile and further decrease substantial investment costs and minimalize operative costs, by adopting G2V mode in off-peak duration and V2G mode when demand is high. EVA can maximize their flexibility provision from both the demand side (G2V) and supply-side (V2G).

1) *G2V Mode:* EVs are functioned as a demand-side managing alternative, forming a flexible electricity consumption supporting renewable power integration.
2) *V2G Mode:* EVs are operated as dispersed generation resources.

The batteries of EVs could inject power to the grid by discharging and forming large-scale distributed electricity storage regulated/controlled by the needs of an electric system. V2G control might offer an important revenue stream that would enhance the economics of grid integrated EVs and additionally motivate their adoption. It could also recuperate grid stability. However, the downside of V2G operation is namely, reduced battery life, additional infrastructure cost, safety issues, etc.

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Utilizing a mobile energy storage system, EV batteries may store electric power which may assist as a grid source during peak periods. Employing distributed energy storage of EVs, EVAs could offer ancillary services viz. spinning reserves and frequency regulation. EV owners can be incentivized for motivation towards offering V2G services. In other words, their market participation can be facilitated to perform charging operation whenever the network experiences less demand and execute discharging at times when there is most demand on the network. Nevertheless, the V2G market entails strict regulations and integration of demand response prioritize are desired to enhance the market efficiency of V2G scheduling. The dynamics of mobility behaviour of EV owners elevates challenges to V2G scheduling of EVA. The EV batteries usage standards are very strict from their state of health aspect. Flexibility services use EV's manageable charging/discharging capability to adapt power rates at the network contact notch. Conventionally this servicing is all activities near elementary charging (whose intention is to upsurge the SOC to and to guarantee energy for driving) and they can be: Regulation-Up attained by decrease/increase of charging/ discharging power in charging G2V/ discharging V2G mode of operation, and start discharging if in idle mode. Regulation-Down realized by increase/decrease of charging/ discharging power, in charging G2V/ discharging V2G mode of operation, and start charging if in idle mode.

II. LITERATURE REVIEW

Baringo, et.al (2023) This study analyzes the bidding strategy problem of an aggregator managing a set of electric vehicles. The electric vehicle aggregator determines the bidding decisions in the market that minimize the charging costs of electric vehicles and, at the same time, meets the driving requirements of electric vehicle users. The models developed in this chapter take into account the uncertainty in both market prices and driving needs using a set of scenarios, which allows formulating the problem using a stochastic programming approach. The impact of the bidding decisions of the electric vehicle aggregator on market prices is also addressed in the decision-making tool. A number of illustrative examples explain how to formulate and solve this type of problems.

Shafie-khah, et.al (2012) A market regulator is considered to increase the market efficiency and hence several regulations are tried to achieve this target. In many of such regulations, special conditions of renewable energies have been introduced. Accordingly, it is observed that some changes in regulations may have indirect undesirable effects on involved companies. In this paper, effects of the changes in market regulations on the behavior of both plug-in electric vehicle owners and their aggregators have been studied. A hybrid method is proposed to simulate the behavior of the market players from both regulator and aggregator's point of views. In addition, behavior of electric vehicle owners has been modeled considering type of the contract with aggregator. The result shows that a clever aggregator can convert some threats to changes in market regulations and there have been opportunities to increase the profit, enhanced the costumers and even the market efficiency.

Sukumar, et.al (2023) A hybrid BCMPO technique for optimal scheduling of electric vehicle aggregators under market price uncertainty is proposed in this manuscript. The proposed method is a combined performance of balancing composite motion optimization (BCMO) and political optimizer (PO); thus, it is known as a BCMPO system. The hybrid optimization system is used in this work to explore the programming of electric vehicle aggregators under market price uncertainty. The proposed electric vehicle aggregator contributes to the market price for increasing profits. To model the uncertainty of market price with the BCMPO system, the higher and lower levels of the upstream grid prices are utilized. The results of the proposed algorithm are utilized to build numerous charging and discharging approaches that may be used via the operator for a robust EV aggregator scheduling under the uncertainty of the upstream grid price. At that time, the proposed model accomplished on MATLAB/Simulink platform performance is related to the existing systems, such as genetic algorithm (GA), particle swarm algorithm (PSO) and elephant herding optimization (EHO).

Jamroen, et.al (2023) In recent years, variable renewable energy sources (RES) have been integrated into electricity generation to reduce reliance on fossil fuels. RES integration into conventional power systems diminishes rotational inertia, causing frequency fluctuation vulnerability. Following the rapid increase in electric vehicle (EV) sales, an EV fleet can contribute to an automatic frequency reserve service in balancing markets through an EV aggregator. However, the benefits of an EV aggregator directly depend on the energy availability of each EV in an aggregator, represented by the state-of-charge (SoC). In the wider literature, SoC estimation is conventionally calculated using the ampere-hour (Coulomb counting) method. However, this approach is vulnerable to estimation errors, such as initial SoC and power measurement errors that can positively or negatively affect aggregator benefits. Although previous studies have examined several ways to maximize aggregator benefits, none has explored the effect of SoC estimation errors on aggregator benefits. Therefore, this study aims to preliminarily explore the influence of SoC estimation errors on aggregator benefits in the frequency containment reserve (FCR) market. The regulatory framework and the FCR market are modeled in the European context. The simulation results demonstrate that SoC estimation errors affected the FCR provision period and forced charging activation, resulting in positive and negative changes in EV aggregator revenues.

Aliasghari, et.al (2019) Electric vehicle aggregator is an agent for facilitating the interaction between grid and electric vehicle owners, which could bring advantages for all of them. Not only could the aggregator participate in the day-ahead market as a representative of electric vehicle owners, but the aggregator could also manage the integrated load of electric vehicles via arranging charging and discharging times in responding to price signals. The current paper presents a novel hybrid stochastic/information gap decision theory optimization technique for decision making of electric vehicle aggregator in uncertain environment. It evaluates the opportunity/robustness of optimal scheduling of electric vehicle aggregators facing with uncertainties. The uncertainties of arrival time, departure time and the initial state of charge of each vehicle are modeled via scenarios, while market price uncertainty in the day-ahead market is formulated with a bi-level information gap decision theory based approach focusing on the gap between forecasted and real values. The objective function is to maximize the expected profit of the aggregator regarding the two contradictory attitudes toward the risk management under the uncertainty of market price, i.e., risk-averse and risk-seeker strategies of information gap decision theory approach. In order to verify the effectiveness of the proposed approach, a case study has been investigated. The results confirm that a risker decision leads to a higher profit. By contrast, the aggregator can implement robustness function to make a more conservative decision to guaranty his predetermined profit in the face with the uncertainties.

Afentoulis, et.al (2022) The massive, uncontrolled charging of numerous plug-in electric vehicles is expected to have an adverse impact on the reliable operation of the electricity networks. The flexible and coordinated management of the charging process, also known as smart charging, is a promising solution that provides the system and network operators with additional flexibility and the electric vehicle users with reduced charging costs. The Electric Vehicle Aggregator (EVA) is the entity that is able to exploit the flexibility potential of smart charging, by optimally managing the complex smart charging process over a distributed network of connected charging stations. Given the inherent complexity and requirements of managing the smart charging process at scale, it is critical for EVAs under development to adopt a well-defined business model that is carefully designed and adapted to the unique needs of their business. Towards this direction, this paper proposes a novel Business Model Framework that is customized for designing and developing viable business models for EVAs. The proposed framework is based on the value proposition, creation and delivery, and ultimately on the value capture, enabling EVAs to identify and unlock the untapped potential of flexible charging in wholesale electricity markets. Thus, it can serve as a roadmap for entities interested in fostering smart charging services. The key aspects of the proposed framework are described in detail, putting an emphasis on the interactions of EVAs with the e-mobility ecosystem. Finally, the proposed framework is utilized to examine one business model for the EVA participation in the EU-based balancing market, using actual market signals and settlement rules, highlighting its practicality under real-world conditions.

Baringo, (2017) This paper analyzes the bidding strategy problem of an electric vehicle aggregator that participates in the day-ahead energy market. The problem is formulated using a stochastic robust optimization model in which uncertainties in the day-ahead market prices and in the driving requirements of electric vehicles are modeled using scenarios and confidence bounds, respectively. The output of the proposed model is used to build the bidding curves to be submitted by the aggregator to the day-ahead market. We assume that the electric vehicle aggregator behaves as a price-taker in this market. A case study is analyzed to illustrate the main features of the proposed approach, as well as its applicability. We also compare the results with those achieved by considering other strategies. Results show that the proposed approach allows the aggregator to reduce the charging costs in comparison with other charging strategies. Moreover, the solution obtained is robust in the sense that driving requirements of electric vehicle users are met.

Alipour, et.al (2016) Plug-in electric vehicles are expected to play a major role in the transportation system as the environmental problems and energy crisis are being more and more urgent recently. Implementing a large number of vehicles with proper control could bring an opportunity of large storage and flexibility for power systems. The plug-in electric vehicle aggregator is responsible for providing power and controlling the charging pattern of the plug-in electric vehicles under its contracted area. This paper deals with the problem of optimal scheduling problem of plug-in electric vehicle aggregators in electricity market considering the uncertainties of market prices, availability of vehicles and status of being called by the ISO in the reserve market. The impact of the market price and reserve market uncertainties on the electric vehicle scheduling problem is characterized through a stochastic programming framework. The objective of the aggregator is to maximize its profit by charging the plug-in electric vehicles on the low price time intervals as well as participating in ancillary service markets. The operational constraints of plug-in electric vehicles and constraints of vehicle to grid are modeled in the proposed framework. An illustrative example is provided to confirm the performance of the proposed model.

Aliasghari, et.al (2020) Selecting an appropriate contract price between electric vehicle aggregators and electric vehicle owners is an uncertain, multi-criteria decision-making issue. In addition, the results can cause strong conflict due to different aims: the optimal value for increasing electric vehicle aggregator (EVA) profit negatively affects the cost for owners. The value of the contract price can change the optimal scheduling of EVAs in the day-ahead market.

Taking into consideration this context, the current paper proposes to solve the multi-objective scheduling problem of an aggregator with a goal programming approach. The presented approach sets a satisfaction level for each goal according to decision-makers' preference. Numerical results illustrate the validity of this approach to balance different performance measures. Furthermore, optimal scheduling of electric vehicle aggregators in the day-ahead market is created.

Wu, Wanli et.al (2023) In the interaction between electric vehicle (EV) and grid, research on the coordinated optimization of different EV aggregators to reduce the adverse effect of EVs uncertainty is of great significance. This paper commits to formulating an imbalanced liability trading cooperation platform among multiple EV aggregators in real-time (RT) market. First, we propose a joint bidding model of multiple EV aggregators in RT market from the individual perspective. Each aggregator optimizes its internal bidding strategy and external imbalanced liability trading simultaneously. Next, considering the self-interest of each EV aggregator, the cooperative model is built based on General Nash bargaining (GNB) theory. To promote EV aggregators to trade but avoid over-dependence, each EV aggregator's bargaining power is formulated by both individual trading quantity and trading dependence. Then, we decompose the model into two sub problems and introduce the Neuro-dynamic-based algorithm for distributed solving. Finally, numerical results show that the proposed coordinated model can reduce the adverse effect of EVs' uncertainties on grid power balance to some extent, and realize cost saving or even profit earning for aggregators.

III. NEED OF THE STUDY

Due to regulatory and physical considerations, Electric Vehicles Aggregator (EVA) is necessary for EVs to participate in electricity markets. The EVA combines the capacities of many EVs and bids their aggregated capacity into electricity markets. EVA as the intermediary between SO and EV owners performs the aggregation and optimization while pragmatically monitoring, controlling and managing the portfolio of EV assets. EVs can be efficiently integrated with the power grid through grid-to-vehicle (G2V) technology. The G2V scheduling of EVA turns out to be an emergent research focus exploring the opportunities and challenges ahead with smart grid integrated EVs ecosystem and electricity markets participation. G2V scheduling can be employed for valley-filling and load leveling. The main objective of this work is to introduce G2V scheduling in multiple electricity markets and to review important problems in the current G2V scheduling problem such as reduction of the EV owner cost, support the power grid, monetize and capture EVs' value, generate revenues for EVA. The streams or stacks of value can be monetized by charging customers' batteries when wholesale prices are low, or discharging them when the opposite is true; and by supporting local distribution networks at times when they are stressed. The more flexible the EVs fleet is, the better positioned market will be to respond to coming changes in power system and transportation sectors, such as the addition of more renewables, the deployment of storage, and the provision of essential grid support services.

With demand-side management, EVA could facilitate EV owners' dynamic market participation, leverage the DR tool to provide ancillary services to SO for the decarbonizing grid. It optimally accomplishes the charging of the EVs, to not only maximize the EV owners' welfare in response to prices and accommodate their driving needs but also to retain the distribution system within its operating bounds. EVA could holistically optimize portfolios of PBDR and G2V ancillary services to get the full benefit of EVs. Optimal G2V scheduling of EVA can empower SO to optimize EVs usage, improve grid stability, and design new customer-centric or customer-first offerings and engagement tools of DRPs. Concerning the smart grid and electricity market, it could be a win-win-win situation for all the involved entities (EVA, EV owners, and SO) through the integration of DR in the G2V scheduling of EVA. If the customer is incentivized to change their behaviour, and if the PBDR program is working as intended, then much of the peak EV charging load would be shifted to desired times. However, for optimal G2V scheduling, EVA faces multiple uncertainties like EV arrival and departure times, initial SOC based on unexpected trip plans, renewable DGs output at the charging station, system load etc.

A. *Assumptions*

1) There is no significant difference of the Electric Vehicle Aggregator Considering Grid Stability and Electric Vehicle Owners' Perspective.
2) There is no significant difference of the Integrated Demand Response and Dynamic grid-to-vehicle scheduling of Electric Vehicle Aggregator Considering Grid Stability.
3) There is no significant difference of the Risk-Based Integrated Demand Response and Static grid-to-vehicle scheduling of Electric Vehicle Aggregator for Multiple Markets

IV. METHODOLOGY

For the purpose of this study, we will divide our study into different sections: -

In this study, firstly we will discussion of the G2V/V2G scheduling framework of EVA and the benefits of integrating DR for its market participation efficiency enhancement. The research gap outlined in this study helps to realize the encouragement for research in the present field of green transportation, and analyses the current issues in the area of G2V/V2G scheduling of EVA.

Secondary, we will investigate an overview of various country practices adopted for EVA's G2V/V2G scheduling, along with underlining the necessary framework adopted. Further different roles of EVAs and their current status and participation in the energy and ancillary services markets for supporting grid stability are illustrated.

And the next section will propose different aspects related to grid integrated EVs and grid support services. These aspects include static charging method, charging strategy, sensitivity analysis of the varying number of EVs and upper limit of charging rate on performance parameters of EVA. And the next section will proposes an integrated DR for improved market operations and a more realistic dynamic smart-charging algorithm. Besides, a stochastic programming approach is used to characterize uncertain mobility parameters (times of arrival and departure; and initial State-of-Charge SOC) and solve the optimization problem.

The next section will elaborates the integrated DR and static G2V model presenting the risk neutral and risk-averse behaviors of EVA considering market price uncertainties. Real consumption data of households will use.

The next section will elaborates integrated DR and dynamic G2V scheduling for risk-neutral and risk-averse EVA considering multiple uncertainties: market price volatility and mobility behavior uncertainty.

Finally, we will discussion of the develops risk-averse integrated DR and V2G scheduling algorithm of EVA in energy and ancillary service markets to maintain an equilibrium among different preferences of involved entities SO, EV owners, and EVA.

A. Statistical Methods And Tools

To conduct the study in a scientific way the following statistical tools are used

1) Percentage analysis
2) T-test
3) Chi-square

V. CONCLUSION

There are various methods to optimize the scheduling electric vehicle aggregator for working in power market. So the statistical tools like percentage analysis, T- test, Chi-square etc. The EV aggregators act as an interface between the grid and EVs and always take the information of EV drivers, such as charging power demand and connection time via the smart meter, and send them to the grid operators. The selection of the optimal strategy is based on the maximum operational profits that could be achieved. The formulation of the operational optimization problem and corresponding constraints is very important for the market-based evaluation of all options. This indicates the importance of taking the uncertainties into consideration while solving the optimization problem.

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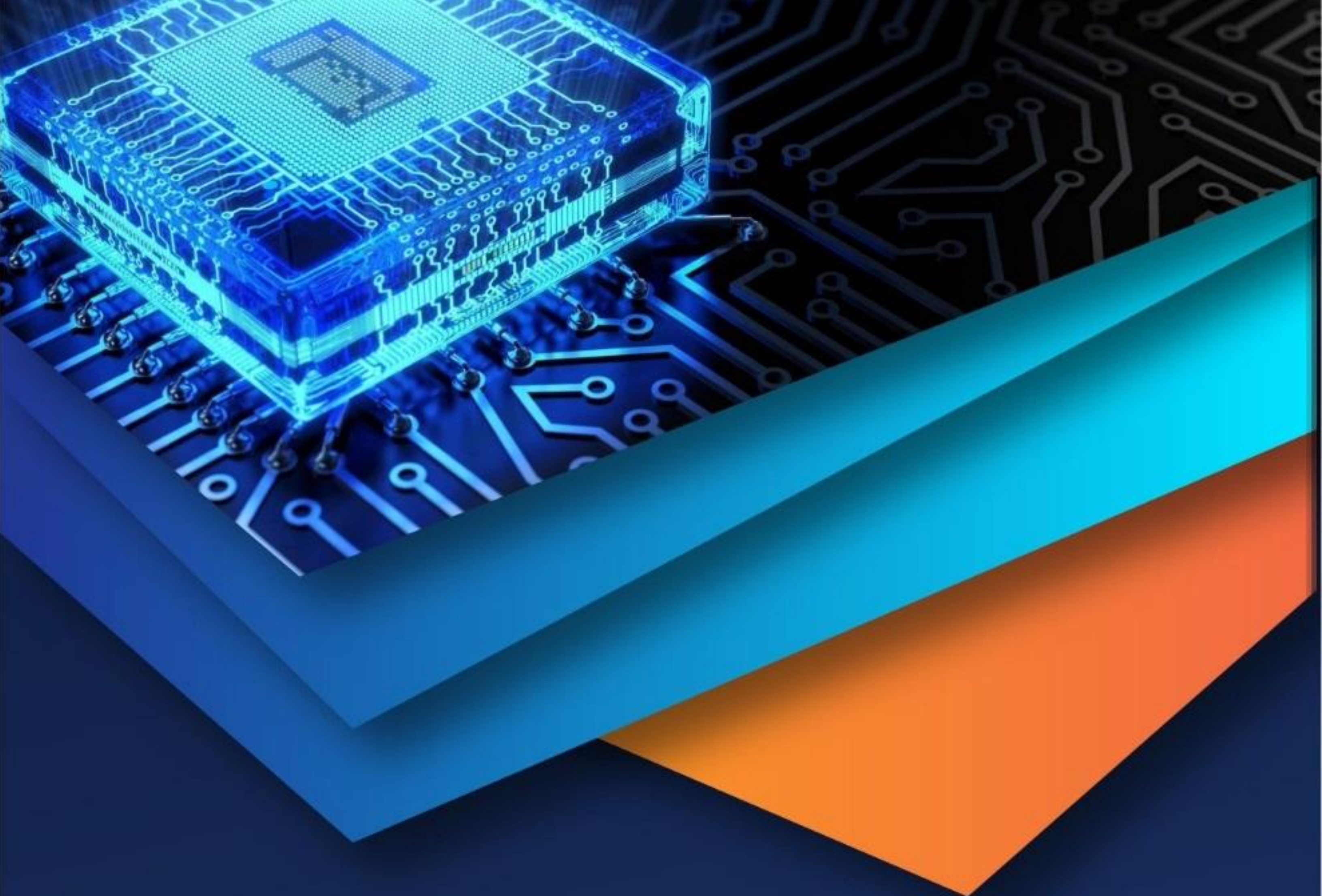

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