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Design and Developments in Different Types of Solar Modified Agricultural Spray Pump: A Review

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Abstract: Pesticide spraying is a major challenge in agriculture for protecting crops from insects. Farmers are currently spraying with hand-operated or fuel-operated knapsack sprayers. This paper addressed various solar sprayers made by various researchers to reduce the human effort when spraying in the field and as part of pollution-free and ecologically friendly green energy. In this article, some of the benefits and limitations of solar sprayers have been found and discussed, and future research needs in green technologies have been highlighted. This study attempts to provide a comprehensive solution to agriculture's future energy requirements. Spraying does not happen all year long. As a result, the same PV (Photo-Voltaic) system used in solar sprayers may be used to power other agricultural operations such as pumping and lighting. Increased pricing and non-availability of traditional power or fuel at peak times in remote areas are two variables that influence their adoption. Farmers' accessible solar sprayers have low field coverage capacities, posing health risks due to direct consumption of spray drift and, as a result, contaminating the environment with engine-powered sprayers. As a result, the focus should be on designing and developing self-contained renewable energy sources that can provide consistent electricity and meet the energy needs of farmers who are far away from their farms.
Keywords: Agricultural Sprayers, Solar Power, pesticides, Agro-spray, Conventional energy, power sprayers, knapsack Sprayers

I. INTRODUCTION

Farmers in the agricultural sector typically engage in fieldwork such as weeding, reaping, sowing, spraying, and other similar activities. Spraying is the most significant operation that a farmer often performs to protect farmed crops from pests, insects, funguses, and diseases. For protection, various insecticides, pesticides, fungicides, and fertilizers are sprayed on crops [1].

Energy independence is essential for a country, and attempts are being made to use renewable energy sources, mostly solar energy, as fossil fuel-based energy is rapidly decreasing. Pesticide spraying is an essential operation in agriculture to protect crops from pests. If pests and diseases are not controlled on time, 18 to 25% of crop production is lost. Spraying liquid solutions uniformly across the crop field is critical for effective pest and disease management. Pesticide spraying is a major challenge in agriculture for protecting crops from insects. Farmers are currently spraying with hand-operated or fuel-operated knapsack sprayers. Agricultural chemical dosage is also important since an underdoes may not provide adequate coverage, and an overdose is costly and can contaminate the food chain through residues. Hand-operated or fuel-operated knapsack sprayers are commonly used by farmers for this task. Because of their bulky and heavy build, traditional sprayers start to create fatigue. Because of the repeated use of the lever and movement in the field with a heavyweight on its back, the typical knapsack sprayer produces user fatigue [2].

Based on the above-mentioned requirements, this review paper discussed various types of solar sprayers developed by various researchers who reduce human tediousness while spraying in the field while carrying a conventional sprayer on the user's back. A few researchers have also designed and developed vehicles to transport the sprayer.

This paper goes through the design of a solar PV sprayer as well as recent improvements in a solar-powered agricultural sprayer.

II. WORKING PRINCIPLE OF SOLAR OPERATED AGRICULTURAL SPRAY PUMPS

It includes a solar panel, a DC pump, a battery charging kit, a pesticide tank, and spray nozzles, among other things. It is powered by solar energy. The solar panel absorbs the solar energy first. This solar energy is converted into electrical energy by the photovoltaic cell. [3].This electricity is then used to charge the battery. After that, the battery will be used to power the DC motor. A DC motor operates a DC pump, which suctions liquid from the intake of the liquid tank. The liquid will then be sprayed from the DC motor outlet through a nozzle linked to the spray pipe.

III. DESIGN OF A SOLAR-OPERATED PV SYSTEM FOR SPRAYING

Components Used: Components are chosen to maximize the product's output. The following are the components that are employed as follows.

A. Tank

A water tank is a water storage container. Water tanks are used to store water for a range of applications, including drinking water, irrigated agriculture, fire control, agricultural farming (both plants and animals), chemical manufacturing, food preparation, and a variety of other uses. The overall design, building materials, and linings of a water tank are all specified in specifications. Plastics (polyethylene, polypropylene), fiberglass, concrete, stone, and steel (welded or bolted, carbon, or stainless) are among the materials used to make a water tank. [4].

B. Nozzle

A nozzle is a device used to control the direction and properties of a fluid flow as it exits (or enters) an enclosed chamber or pipe (especially to improve velocity). A nozzle is a pipe or tube with a variable cross-sectional area that can be used to guide or change the flow of fluid (liquid or gas). The flow rate, speed, direction, mass, shape, and/or pressure of the stream that emerges from nozzles are widely used to control them. The velocity of fluid increases in a nozzle at the price of its pressure energy [5].

C. Solar Panel

Solar energy is likely the cleanest and most dependable kind of renewable energy today, and it can be used to power appliances in a variety of ways. Solar-powered photovoltaic (PV) panels use photons of light from the sun to excite electrons in silicon cells, converting sunlight into electricity. This electricity can then be used to charge a battery with renewable energy. These panels not only pay for themselves over time by cutting power bills, but they also help to minimize air pollution generated by utility companies [6].

D. Charge controller

The rate at which electric current is added to the battery is limited by the charge controller. As a result, overcharging and overvoltage are avoided. It uses the Pulse Width Modulation (PWM) technique to gradually stop charging the battery when it exceeds a preset high voltage level and gradually re-enable charging when the battery voltage falls below the safe level [2].

E. Dc Motor Pump

A pump is a device that uses mechanical action to transport fluids. Pumps use energy to do mechanical work by pushing fluid through certain devices. A geared DC motor has a gear assembly attached to it. RPM stands for revolutions per minute, and it is used to measure the speed of a motor. The gear assembly aids in boosting torque while decreasing speed. A gear motor's speed can be decreased to any desired figure by using the right arrangement of gears. Gear reduction is a concept in which gears reduce the vehicle's speed while increasing its torque. This Insight will go over all of the tiny and large details that go into making a gear head and, as a result, how a geared DC motor works [7].

F. Battery

Electric batteries are made up of one or more electrochemical cells and are used to power electrical devices such as flashlights, smartphones, and electric cars. When a battery is supplying electric power, the positive terminal is the cathode, and the negative terminal is the anode. The negative terminal is the source of electrons, which flow and supply energy to an external device when linked to an external circuit. When a battery is connected to an external circuit, electrolytes within the battery can travel as ions, allowing chemical reactions to be completed at the terminals and thereby delivering energy to the external circuit. Current flows out of the battery due to the mobility of those ions within the battery [7].

IV. DESIGN CALCULATION FOR PV SYSTEM FOR SPRAYING

A. Electrical Power

The amount of electric current flowing as a result of a given voltage is known as electrical power. It's the amount of power needed to start or run a load for one second. Watts (W) are the units of electrical power. (Patil *et al.*, 2014) [8].

Power = voltage x current

$P = V \times I$

Where P denotes power (watts), V denotes voltage (volts), and I denotes current (A).

B. Efficiency of Solar Panel

The solar panel's efficiency is defined as the ratio of energy output to energy input from the sun. The efficiency of solar cells can be estimated using the following formula (Patil et al., 2014) [8].

The power conversion efficiency of the panel $= \frac{P_{out}}{P_{in}}$

$$\text{PV Efficiency (\%)} = \frac{Output\ Power(Watt)}{Input\ Power(Watt)} \times 100$$

$$\text{PV Efficiency (\%)} = \frac{Voltage\ produce\ (V) \times Current\ developed(A)}{Corresponding\ solar\ intensity(\frac{Watt}{m^2}) \times area\ of\ the\ array(m^2)} \times 100$$

The quantity of energy produced during the day is measured in watt-hours. Due to the material properties of solar cells, they perform best at low temperatures. When the operating temperature rises, all cell materials lose efficiency.

C. Pumping Efficiency

Pumping efficiency is defined as the ratio of the amount of energy required to deliver water to the amount of energy supplied by the array (Patil et al., 2014) [8].

$$\text{Pumping Efficiency (\%)} = \frac{Power\ needed\ to\ deliver\ water(watt)}{Power\ supply\ by\ array\ (Watt)} \times 100$$

$$\text{System Efficiency (\%)} = \left(\frac{PV\ efficiency(\%)}{100} \times \frac{pump\ efficiency(\%)}{100} \times 100\right)$$

D. Power Requirement for Pump

The capacity of the spray pump is chosen using the formula below, based on the head and discharge requirements (Narete et al., 2016) [9].

$P = \frac{\rho \times g \times Q \times H}{1000 \times \eta}$

P = Power required to drive the pump, in Watt.

ρ = Density of the liquid, kg/m^3 (Density of water=1000 kg/m^3).

g = Acceleration due to gravity 9.81 m/sec^2

Q = Flow or liquid discharge, (m^3/sec).

H= $Total\ pump\ head, m$

η = Overall efficiency of the pump (Assume 60%)

Q= $A \times V = a \times v$ (Patil et.al, 2014)

Q= Flow rate (m^3/sec)

A = Area of the cross-section of pipe (m^2).

V = Velocity of flow in a pipe (m/sec).

a= Area of the nozzle outlet (m^2).

v= flow velocity at the nozzle exit (m/sec)

Total pump head (H) was calculated by

$H= H_{stat}+V_h+h_f$

Static head (H_{stat}) was determined by

$H_{stat}= h_s+h_d$

Where,

H_{stat} = Static head (m)

h_s = Static suction head (m)

h_d = Static delivery head (m)

Velocity head (V_h) was determined by

$V_h = \frac{(V_s)^2}{2g} + \frac{(V_d)^2}{2g}$

Where= $\frac{(Vs)^2}{2g}$ = Velocity head in suction (m)

$\frac{(V_d)^2}{2g}$ = Velocity head in delivery (m)

g= Considering Acceleration due to gravity is 9.81 m/sec^2

$$\text{Velocity at suction } (V_s) = \frac{\text{Discharge}}{\text{Area of the suction pipe}}$$

$$\text{Velocity at discharge } (V_d) = \frac{\text{Discharge}}{\text{Area of the delivery pipe}}$$

Friction head h_f was determined by

$$h_f = \frac{4flV^2}{d \times 2g}$$

Where,

h_f = Head lost in the pipe, m

f = Coefficient of friction for the pipe

l = Length of the pipe, m

V = Velocity of the flow in the pipe, m/sec

g = acceleration due to gravity, 9.81 m/sec^2

d =Diameter of pipe, m

Total pump head (H) was determined by

$$H = H_{stat} + \frac{(V_d)^2}{2g} + h_f$$

Where, H = Total pump head, m

A suitable pump is chosen from the market based on head, discharge, and power. The battery is selected based on the voltage rating and current of the selected pump.

E. Selection of battery

The battery is chosen based on the amount of power and voltage required to drive the pump.

Battery current rating in Ah (I) = Power (P) of the running pump in watts/Voltage (V)

F. Selection of solar panel

Solar panels are chosen based on battery output power and effective sunshine hours. When the battery is connected to the solar panel via a charge controller, the solar panel is subjected to some load, resulting in a short circuit.

Open circuit voltage × Short circuit current = Actual solar panel power

G. Calculation of current produced by solar

The maximum power (P) of the solar panel and the voltage rating (V) of the battery was used to calculate the current produced by the solar panel (I).

$$\text{Current produced by solar panel (I)} = \frac{\text{Max power of solar panel}(P)}{\text{Voltage rating of battery (V)}}$$

H. Calculation of battery charging time

$$T = \frac{\text{Battery rating (Ah)}}{\text{Current supplied by panel (I)}}$$

V. DIFFERENT DESIGNS OF SOLAR SPRAY PUMP

Patil et al. (2014) reviewed a solar-powered knapsack sprayer created with a 37-watt solar panel that allows it to be used in two modes: battery mode and solar panel mode. The overall model design places the weight of the panel as well as the weight of the sprayer on the operator's shoulder, allowing for easy operation. After 5 hours of operation at full solar intensity, the sprayer can continue for another 2.5 hours. At a walking pace of 0.7 m/s, the sprayer can spray 360 liters/ha of liquid in 4.00 hours. The sprayer discharge rate was 0.0267 liters per second.

Joshua et al. (2010) converted an old fossil-fueled power sprayer into a solar sprayer modified. A solar sprayer model was built and introduced for effective operation without fossil fuel to address the limitations of the previous model and to minimize the running cost of the power sprayer. The two-stroke petrol engine was replaced by a single motor in this modified model. The electrical energy stored in the 12V battery attached to the unit was used to power it. The solar panels may charge the 12V battery [10].

Nitesh A. Pachpor et al. (2019) made a comparison between the Solar Trolley Type Sprayer and the Solar Knapsack Sprayer, as well as the performance characteristics, using the two models above, and came up with the following conclusion: The sprayer's discharge rate was measured in both laboratory and field conditions, and the average discharge rate was about 0.023 l/s (82.8 l/h) in both. The sprayer's effectiveness was evaluated in farmers' fields for spraying different crops such as cotton, green gram, onions, and so on. This study examined the performance parameters of a solar trolley sprayer and a knapsack sprayer. The complete apparatus is transportable and may be operated by a single person. It consists of a 20-watt solar panel, a 12V DC battery charged by the solar panel's solar energy, a DC motor powered by the battery, a pump to spray the pesticide, and a tank to hold the pesticide (in the form of a solution or liquid). The field test was a success [11].

Yallappa et al. (2016) built and tested a solar-powered sprayer that included a 20 W solar panel, a 12V DC battery charged by solar energy received by the solar panel, a DC motor driven by the battery, a pump to spray pesticide, and a tank to hold the pesticide. The complete apparatus is transportable and may be operated by a single person. The sprayer's discharge rate was measured in the lab and the field, and the average discharge rate was around 0.023 l/s [13].

Swami et al. (2016) created and built a solar PV-powered sprayer that can be transported in the field using a manually operated vehicle. The proposed solar PV sprayer can work in both direct and indirect modes. The sprayer was operated in both direct and indirect modes, with the direct mode using power generated by a 100 (Wp) Watt Peak polycrystalline PV module mounted on the sprayer and the indirect mode using stored electric energy in a deep-cycle battery (12 V, 32 Ah). In all modes, a 60-watt DC motor pump was used to generate the required operating pressure for spraying liquid pesticide formulations [12].

VI. EXISTING SOLAR SPRAYING TECHNIQUES' BENEFITS AND DRAWBACKS

Some advantages and disadvantages of solar sprayers have been found and explored based on the reviews in the paper. It has been found that in manual backpack spraying, the worker must carry the entire weight of the pesticide-filled tank, which produces the laborer’s weariness and hence lowers human capacity. The proper pressure is not maintained, which has an impact on droplet size and uniformity of distribution. During spraying, the operator is exposed to dangerous pesticide spray drift, putting his or her safety at risk.

By replacing the fuel engines with DC motors, existing power knapsack sprayers were turned into solar sprayers. During the operation, back pain caused by vibration was detected. The operator's safety is also in doubt, as he is constantly exposed to hazardous pesticide spray drift while spraying. The removal of toxic exhaust emissions may result in a cleaner atmosphere.

Trolley-based solar sprayers have a lot of pushing action, which makes the operators tired. Additionally, these sprayers have a smaller field capacity, and operators are exposed to chemicals as they travel behind the spray pattern.

Table. I Comparison Between Existing Power Sprayers and Developed Solar Sprayers

Existing Power sprayer	Developed solar sprayer
Operating system: use fuel	Operating system: use solar energy (without fuel)
Working Model: two stoke petrol engine with fuel	Working Model: Battery operated DC motor
The unit cost of a power sprayer with an engine is Rs/- 4000 to Rs/- 5000	The unit cost of a power sprayer without an engine is Rs/- 3900
Operating cost per hour: Rs./-70 to Rs./-75.	Operating cost: Nil
Maintenance required	Maintenance Free

Table. II Summary of Solar Sprayers Developed and Their Performance Evaluation

Sr .No	Reference	Type of sprayer	Research findings
1	Joshua et al. (2010)	Modified solar sprayer	Designed a power sprayer with a two-stroke gasoline engine. Because the operating costs were discovered to be high, they proposed a solar-powered sprayer
2	Patil et al. (2014)	Solar operated knapsack sprayer	A solar-powered knapsack sprayer was tested and found to be capable of spraying 360 liters/ha. The sprayer's discharge rate is 0.0267 liters per second for 4.00 hours at a walking speed of 0.7 m/s.
3	Swami et al. (2016)	Trolley based solar sprayer	The developed solar PV sprayer's performance on a manually operated vehicle has been field-tested and determined to be satisfactory for spraying pesticides on various arid crops. At Jodhpur station, the sprayer is best operated between 9:00 AM and 3:00 PM.
4	Yallappa et al.(2016)	Portable solar-powered sprayer	The sprayer's theoretical and effective field capacities were 0.17 ha/h and 0.14 ha/h, respectively, at 2.8 km/h walking speed and 0.60 m swath width.

Table. III Technical Specifications of Different Types of Solar Sprayers

Sr. No.	Reference	Type of sprayer	Technical specifications of solar sprayer components		
			Dc Motor Pump	Battery	Solar Panel
1	Joshua et al. (2010)	Modified solar sprayer	Current: 7A Voltage: 12V Power: 82W	Power: 84W Voltage:12V Current: 7A	Power: 75W Voltage: 15V Current: 5A
2	Patil et al. (2014)	Solar operated knapsack sprayer	--------	Dry lead battery Voltage:12 volts Capacity: 7.0Ah	Power:37W Voltage: 16.4VDC
3	Swami et al. (2016)	Trolley based solar sprayer	Power: 60W Volts: 24V Amps: 2.5A Discharge: 5.0 lpm (liters per minute)	Voltage: 12V Current: 25Ah Weight: 16 kg No. of batteries: 2	Power: 50W Voc: 21.9V Isc (short circuit current): 3.18A Module efficiency.: 13.1% No. of modules: 2
4	Yallappa et al.(2016)	Portable solar-powered sprayer	Power: 82 W Voltage: 12V Current: 7A Speed: 1600 rpm Weight: 1 kg	Voltage: 12V Current: 7 A	Size: 0.5m x 0.3m Peak power: 20W Voltage: 17V Weight: 1 kg

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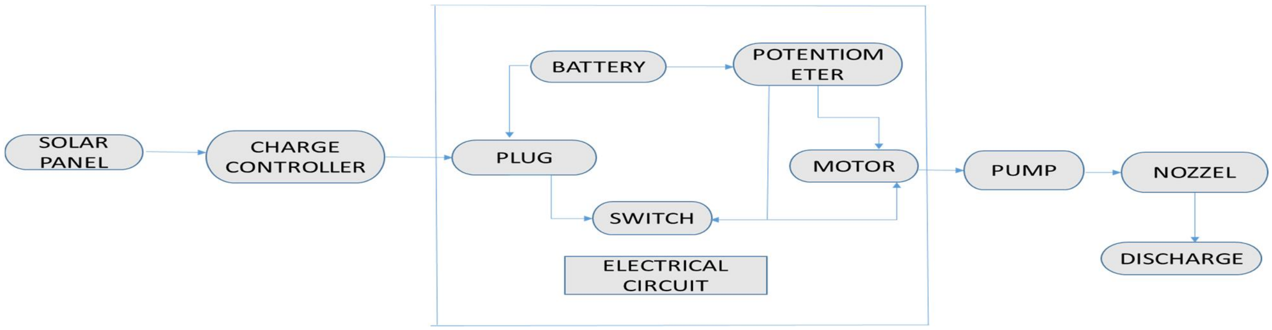

Fig. 1 Block diagram of spraying system

Fig.2 Solar operated trolley type sprayer

Fig.3 Fabricated solar pesticide sprayer (back sprayer)

VII. RESULTS AND DISCUSSION

Solar sprayers run on solar power, so they have low operating costs. They are also pollution-free and environmentally friendly. The majority of solar sprayers are created by modifying existing knapsack sprayers. The knapsack sprayer's petrol engine has been replaced by a DC motor and a solar PV panel, but the rest of the operation remains the same. As a result, it is necessary to design and develop a scientifically and compact-sized boom sprayer that can be used on major crops and is powered by solar energy. It should also ensure the operator's safety and reduce health risks. Solar energy can be used for spraying, water lifting, and lighting by providing a movable solar energy power unit that can perform the necessary farm operations. There is a need for such a solar power unit with attachments for spraying, water lifting, and lighting to improve the livelihoods of small and marginal farmers.

Many farm locations do not have access to conventional electricity, and many remote locations do not have access to grid energy. It is also difficult for the government to provide electricity to every farmer in every location where it is required. Where conventional electricity is available, it is not supplied for a long time, and frequent power outages occur. One of the factors influencing the use of conventional electricity or fuel is rising prices and a lack of availability during peak hours in rural areas. As a result, there is a need for an independent alternate power source, such as solar energy, that can be used for water lifting in remote locations to meet the domestic and irrigation needs of small and marginal farmers.

Finally, in the future, a multi-nozzle sprayer may be designed with a high-power motor in the system to increase area coverage while reducing time and labor requirements.

A focus should be given to replacing conventional energy sources with solar energy techniques because solar energy is free, unlimited, pollution-free, and environmentally friendly green energy for agricultural sprayers and other farm operations. Other than spraying, the developed solar energy cart could be used to power a variety of farm operations.

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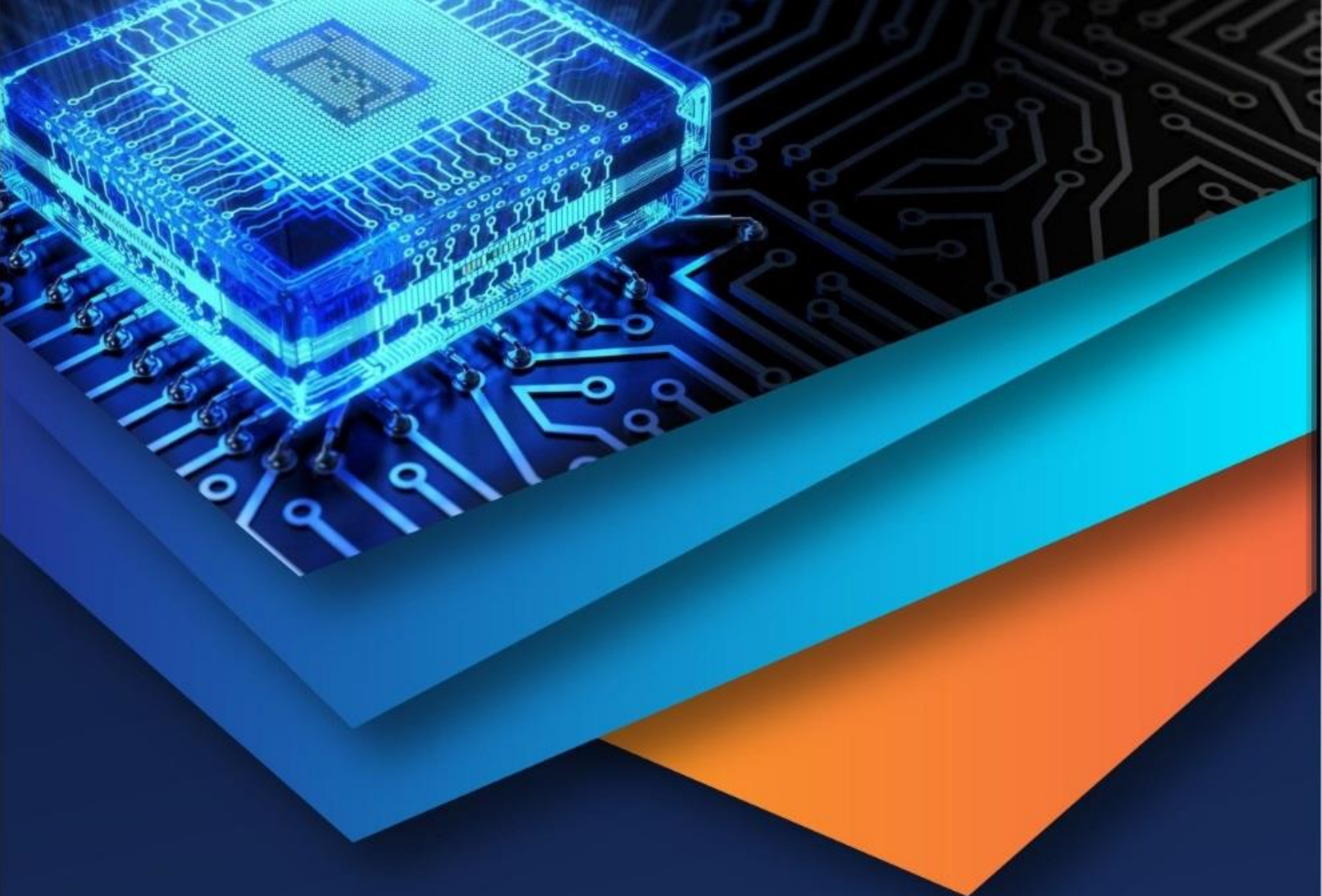

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