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DESIGN AND DEVELOPMENT OF HEXACOPTER FOR CONTROLLING CROWD

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Abstract: Nowadays use of big manned helicopters and other aerial vehicles could be replaced for some applications by UAV's, this makes the applications become cheap and accessible. This also helps in economy and risk of operation of the aerial vehicles. UAV's have been widely used for the purposes like disaster scouting, supplying medical aids and extreme rescue operations and they could prove themselves far worthy and economical than its counterpart.

This Hexacopter for Controlling Crowd focuses on the navigational capabilities of the Hexacopter system and how well it could be made to move between locations and control the crowd. The performance of the platform was sufficiently upgraded, allowing it to be operated in a much more precise, controlled manner which would have been needed for our intended applications.

The UAV designed and developed is a multirotor with six propellers (technically called as hexa-copter). It can vertically take-off and land with the purpose to take aerial surveillance and control the crowd. Understanding and dealing with safety aspects of crowd dynamics in mass gatherings of people related to sports, religious and cultural activities is very important, specifically with respect to crowd risk analysis and crowd safety.

In this regard, efficient monitoring and other safe crowd management techniques have been used to minimize the risks associated with such mass gathering. An example of these techniques is real-time monitoring of crowd using a UAV (Unmanned Aerial Vehicle). In this paper, a crowd monitoring system has been proposed and tested using a bomb dropping technique i.e a smoke granite with be launched in order to control crowd.

This paper also presents the non-radiative method of wireless power transmission technology to be applied for the battery charging system of drones which refers to unmanned aerial vehicles. This wireless charging system enables the continuous charging and efficient duties to overcome the limits and the time allocation, where the hexacopter will move to the designated location. The DC-DC converter system capable of charging 100W class transceiver and drone battery through the inductance mapping of the transmitter and receiver in the frequency band of 13.56Mhz, changing the shape and position of the transmitting and receiving antenna, the efficiency was confirmed to be more than 50%. Therefore, if the unmanned charging system is used for this hexacopter, it is possible to increase the utilization of the hexacopter by the efficient arrangement of the duty range and can be maintained by the present power source. The main goal is to reduce the required human resource and time in controlling the crowd. The advantage of this is an increased capability at low cost and at lower risk in terms of cost and safety.

Keywords: UAV.

I. INTRODUCTION

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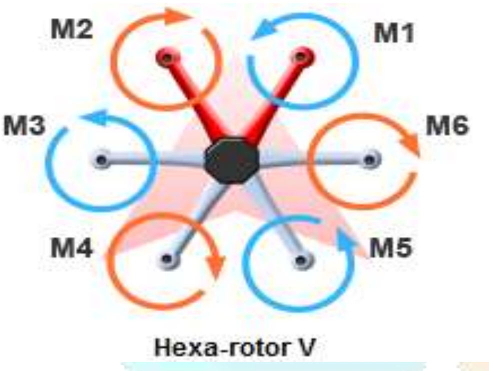
Different models of small, remote controlled UAV‟s are available commercially. Here the model being currently used is a Hexacopter, a small helicopter-like vehicle with six sets of rotor vertical blades, as shown below. A Hexacopter was determined to be the most suitable design, it was capable of vertically taking off, but also had redundant components in case of failure.

The F550 has its rotors arranged in a Hexa-V formation, as is shown in figure 1, where the six blades are spaced equidistant around the outside of the Hexacopter, each spinning in the opposite direction to those adjacent to prevent the Hexacopter from rotating. Two of the arms form a „V‟ at the front of the craft and are colored red to help the pilot identify which way the craft is facing while it is in the air. Unmanned Aerial Vehicle (UAV) becomes popular in the world of science because of its various applications in this life such as search and rescue, monitoring, firefighting, surveillance, agriculture, aerial photography and others. Based on its lifting mechanism, the UAV is divided into two type's i.e. rotor wing and fixed wing. The multirotor included in the rotor wing group is categorized into helicopter, tricopter, quadcopter, hexacopter, and octocopter by the number of propulsion motors. Many researchers are conducting the research in the area of attitude and altitude quadcopter movement control, autonomous helicopter control tricopter modeling, modeling and controlling hexacopter. The control types that are used in this multirotor study i.e PID controllers, PID +LQR, sliding mode controllers, feedback linearization, back stepping, and Neural Network.



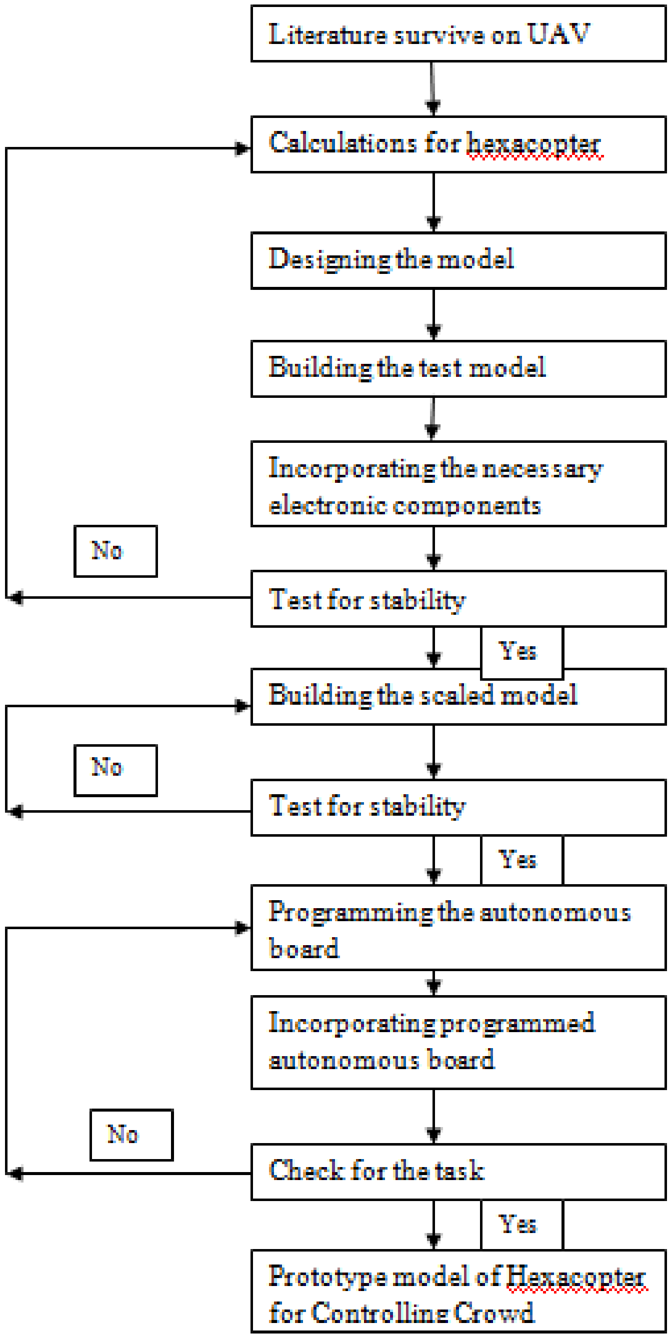
Advantages of the multirotor were included the ability of vertical takeoff and landing (VTOL) does not require arunway to fly, hovering ability and maneuver to perform the mission. The differences in the multirotor type related to the difference in the ability in lifting the load due to the additionof motor, while poses a new problem that causes the system to become more nonlinear and difficult to control. Since our mission is to lift a heavier load, the main choice of the multirotor type is octocopter or hexacopter. Although the octocopter has the ability as a hexacopter, it cost more pricedue to the more number of the motors.

II. MATERIALS AND METHODOLOGY

The key considerations while selecting the materials for designing the Hexacopter model are

- Light weight material
- Strong enough to support its operational weight and structural load
- Availability & cost of the material

The methodology followed in the Design and Development of Hexacopter for Controlling Crowd is as represented in the flowchart below.



These are the fundamental requirements to start with our project.
Our model will have an ability to hover, by generating enough thrust & also it has enough control.
Manoeuvrability in all directions of a three-dimensional plane
It should have Sufficient endurance of not less than 10-15 minutes
Comparatively the body of the model is light-weight, including a battery with the highest power to weight ratio.
The design of hexacopter has been done by using CATIA V5 software. The design is done in such a way that there should not be any damage to the propellers, motors and electrical equipments. The central hub, arms and spars are designed individually and then assembled.
The modeling of the design concepts were realized using CATIA V5 R20, design tool by Dassault systems. Some of the initial concept designs adopted for the drone are shown in the following figures:
The drone is powered by a 22V, 16000 mAh, 6-cell Li-Po battery. The battery powers six brushless DC motors having 330kV torque through specially designed ESCs (Electronic Speed Controllers).
ESC is an electronic circuit used for the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake. An ESC can be used as a stand-alone unit which plugs into the receiver's throttle control channel or can be incorporated into the receiver itself, as is the case in most toy-grade Remote controlled vehicles
The motors are in turn fitted with propellers having a diameter of 17 inches and a pitch of 5.5 inches. All the electronic equipment's are connected to a power distribution board, which controls the distribution of power from the battery to various electronic devices connected to it.
Design of Hexacopter Figures 1, 2 & 3 shows the preliminary CAD diagram of a haxacopter with different views. Figure-1 show the front view of hexacopter, Figure-2 show the isometric view of hexacopter for provide more stability and survives in the forest regions. Figure-3 shows the top view of hexacopter

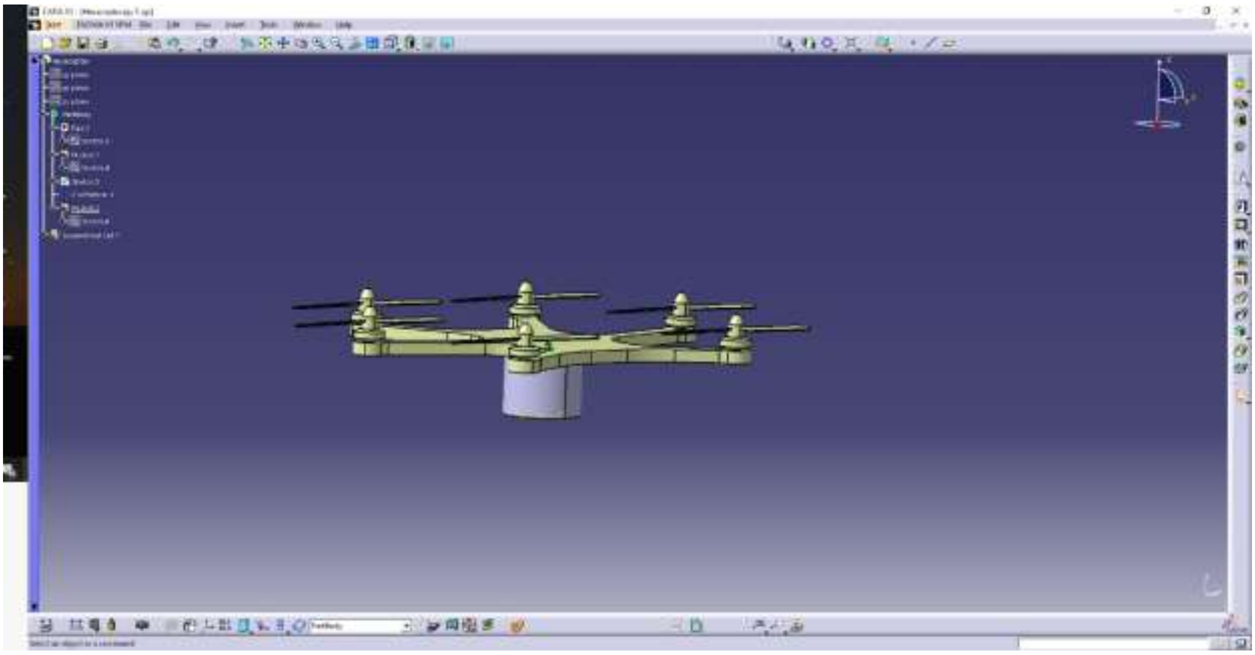


Figure-1 Front view of hexacopter

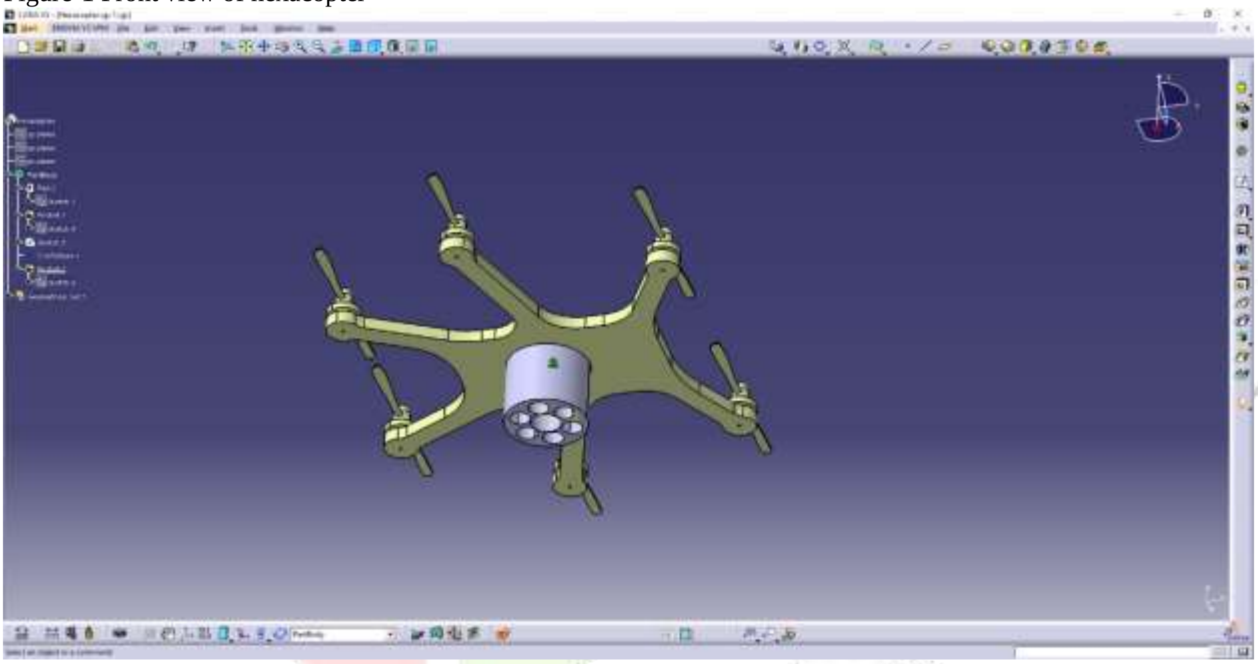


Figure-2. Isometric view of hexacopter.

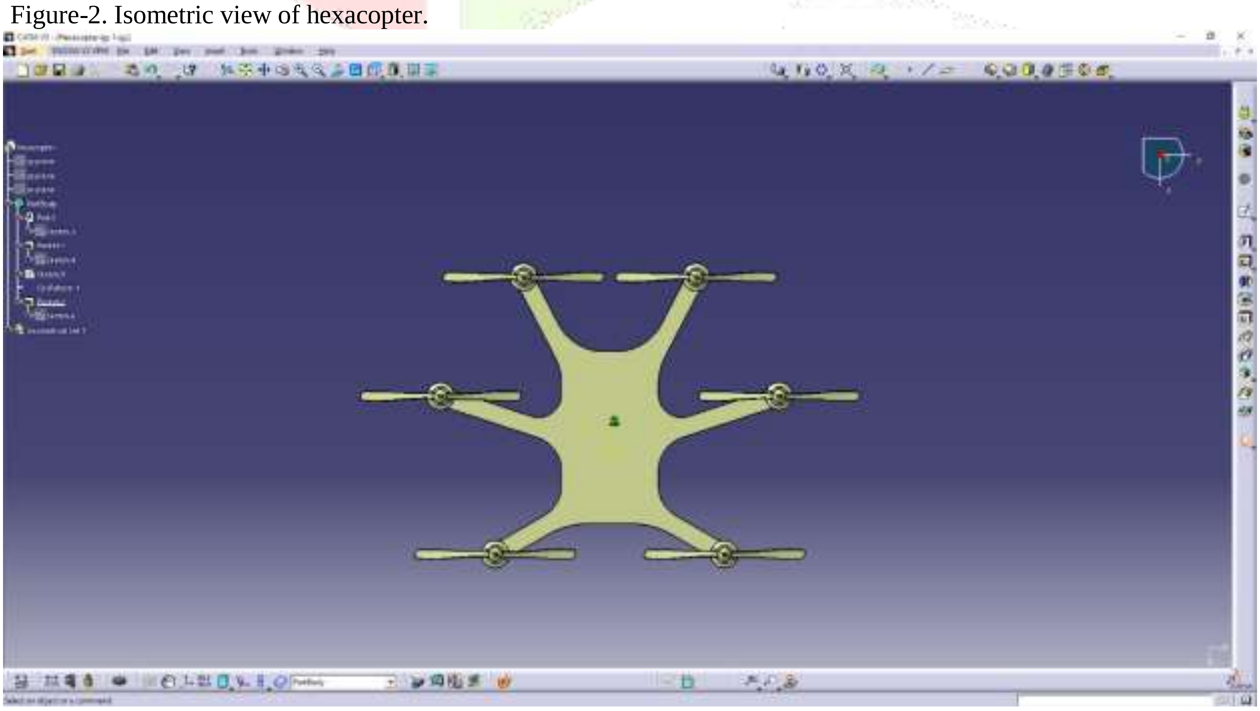


Figure-3 Top view of hexacopter

After the completion of the design of the model using CATAI software, we have used ANSYS software to check the strength of our model.

Structural analysis was done using ANSYS FLUENT tool version 17.0. Here we have considered three parameters for structural analysis of the materials used in the model design, the parameters are total deformation, Von-Mises stress and equivalent strain are the parameters considered for structural analysis. Deformation is defined as transformation of a body from a reference configuration to a current configuration. A configuration is a set containing the positions of all particles of the body. A deformation may be caused by external loads, body forces or changes in temperature, moisture content, or chemical reactions, etc. Von Mises stress is used to determine if a given material will yield or fracture. It is mostly used for ductile materials, such as metals. Elastic strain, a form of strain in which the distorted body returns to its original shape and size when the deformation force is removed.

Aluminum alloy considered has a density 1.49e-0.06 kg mm-3; tensile yield strength of 280Mpa and Tensile Ultimate Strength is 310Mpa, Whereas, Epoxy Carbon UD(prepreg) has a density: 1.49e-0.06 kg mm; Tensile yeild strength of 0.916-3790 Mpa and Tensile Ultimate Strength of 310 Mpa.

Al alloys constituents the parts like arms, motors, mini-rocket, rotatory disc, clamp, casing and the integral part of the hexacopter. The body frame includes base plate, top plate and leg frame constitute epoxy carbon as materials.

The Hexacopter frame is made from plastic and fiberglass of high quality and ultra-durable materials. Whereas the main frame board is high quality glass fiber and the arms are constructed from ultra-durable polyamide nylon. Their arms are reinforced and much stronger, so this succeeds in preventing and reducing arm breakage.

Integrated PCB connections for direct soldering the ESCs. Colored arms for orientation to keep the flight in the right direction, larger mounting tabs on main frame bottom plate for easy accessories mounting. Easy assembly, great feature of this frame is the large mounting tabs at the front and rear of the main frame bottom plate for mounting the lunching system, wireless charging system, and other accessories.

Design of Hexacopter

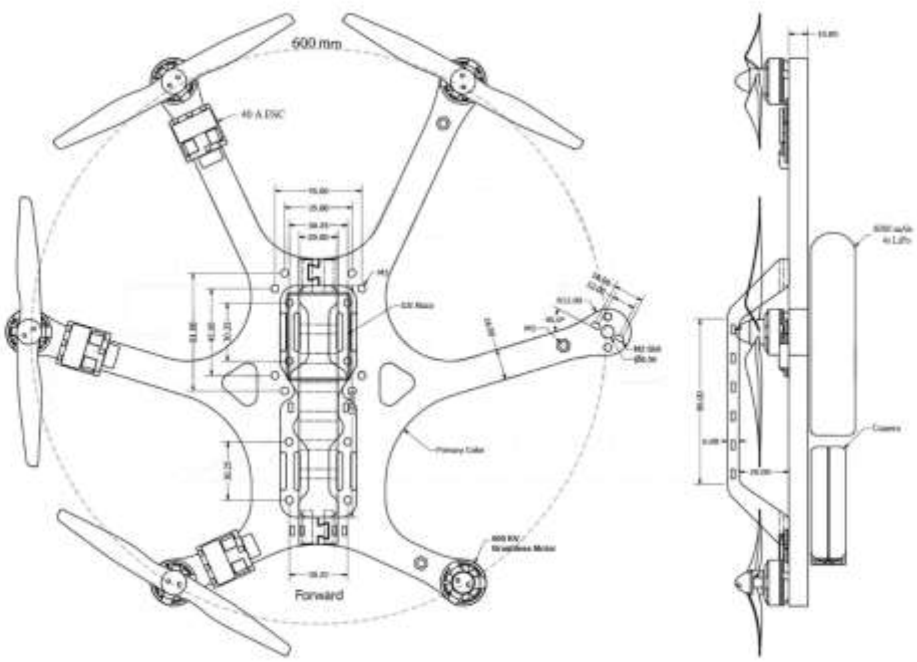


Figure 1: 2D drawing of the Hexacopter.

Hexacopter working principle

The hexacopter is simple design with six rotor propeller with controller. The flight controller is one of the major part of this vehicle. It works on the principle of Newton's "3rd" law of motion " For every action there is an equal and opposite reaction". Hexacopter is a device with a intense mixture of Electronics, Mechanical and mainly on the principle of Aviation.

The Hexacopter has 6 motors whose speed of rotation and the direction of rotation changes according to the users desire to move the device in a particular direction (i.e. Takeoff motion, Landing motion, forward motion, backward motion, right and left motion).

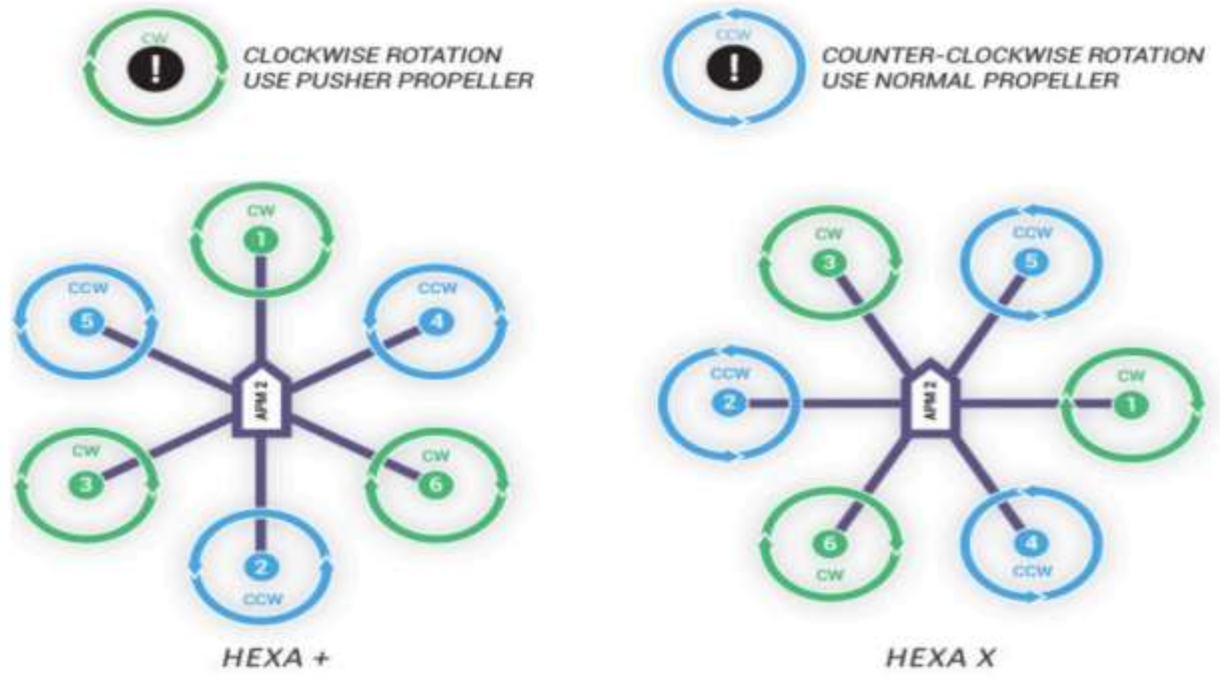
The six rotors creates differential thrust and the hexacopter hover and move accordance with the speed of those rotors.

Hexacopter movement mechanism

Hexacopter can have described as a small vehicle with six propellers attached to rotor located at the cross frame. To control the hexacopter motion fixed pitch rotors are used. The speed of these six rotors are independent. By independent pitch, roll, and yaw attitude of the vehicle can be control easily. The basic three motions in the Hexacopter are:

Hover: All the propellers are operated at approximately the same speed and therefore produce approximately the same thrust. Since all the propellers are equally spaced from the center of gravity, the thrust of the propellers produces no net rotating torque on the aircraft. Additionally, the hexacopter uses three clockwise (CW) rotating propellers and three counter-clockwise (CCW) rotating propellers so that the propeller torque is canceled when they are operating at equal speeds. In hover, the total upward thrust balances the downward gravitational force, and the multicopter maintains zero pitch and roll angles in zero wind (drag) conditions.

Roll Control : A hexacopter can be controlled about its roll axis by increasing the speed of the propellers on one side and decreasing the speed of the propellers on the other side. When the thrust increase on one side is the same as the thrust decrease on the opposite side, the net thrust remains the same. Similarly, the net effect of torque remains the same.



Pitch Control : For a hexacopter, pitch control is analogous to roll control. The thrust differential between front and rear propellers causes the hexacopter to pitch; if thrust is increased in the rear propellers and decreased in the forward propellers, the hexacopter pitches forward.

Yaw Control : Yaw control is achieved by balancing the clockwise propeller rotational torques with the counter-clockwise propeller rotational torques. By spinning the counter-clockwise propellers faster than the clockwise propellers (or vice versa), the opposite net reaction on the hexacopter induces a rotation in yaw.

Take-off & landing motion mechanism : Take-off is movement of hexacopter that lift up from ground to hover position & landing position is versa of take-off position. Take-off (landing) motion is controlled by increasing (decreasing) speed of six rotors simultaneously which means changing the vertical motion.

Forward and backward motion : Forward (backward) motion is controlled by increasing (decreasing) speed of rear (front) rotor. Decreasing (increasing) rear(front) rotor speed simultaneously will affect the pitch angle of the hexacopter.

Left & right motion: For left and right motion, it can be controlled by changing the yaw angle of hexacopter. Yaw angle can be controlled by increasing (decreasing) counter-clockwise rotors speed while decreasing (increasing) clockwise rotor speed.

Tear Gas Dropping Mechanism:

The tear gas dropping mechanism consist of cylinder which contains the tear gas grenades, trigger, slots which holds the tear gas grenades, Dual shaft DC motor connected to a switch in series.

Cylinder: The cylinder in this mechanism acts as the housing for all the components. It's thin and its Diameter (20.96cm) but strong enough to withstand all the elements during the flight.

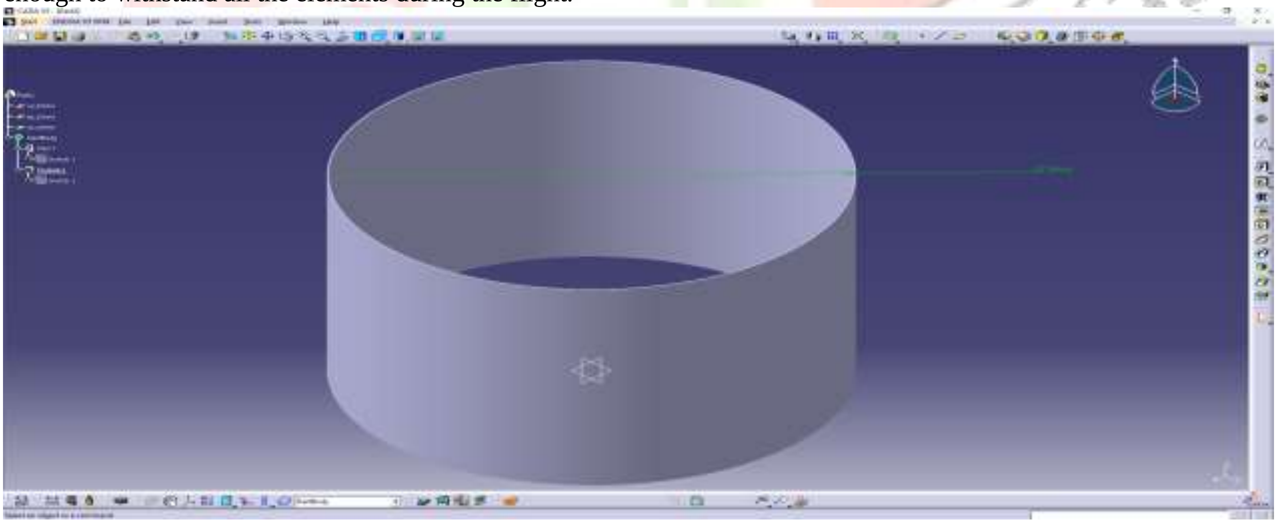
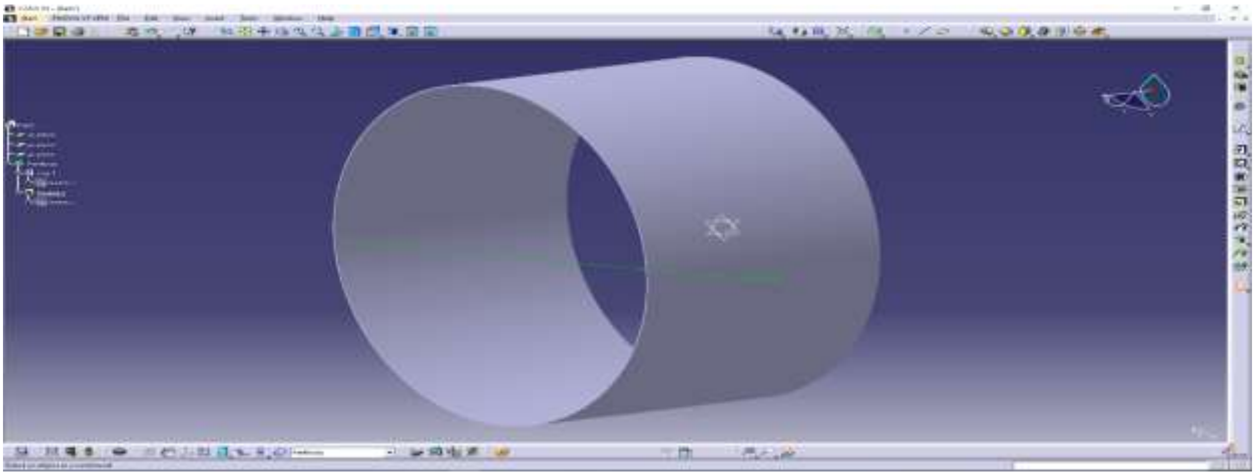


Fig: Cylinder in 3D



Tear Gas Grenades:

The tear gas grenade as the name indicate is one of the type of the grenades which is used to separate the crowd during protest this type of grenade contains chemical which when its launched the smoke coming out of it cause difficulty in breathing and eyes to tear. It comes with various sizes the one which we are using in our application has the following specifications:

Size(Length)=122mm+-2mm
Diameter=40mm+-1mm
Weight=169g+-5g
Outer shell: Plastic

Fig: Tear Gas Grenade.

Dual shaft DC motor

Dual shaft DC motor with gearbox which gives good torque and rpm at lower voltages. This motor can run at approximately 200rpm when driven by a Dual Li-Ion cell battery at 6 V and approximately at 300 rpm when driven by a 9V Li-Ion cell. It is most suitable for light weight vehicle running on small voltage. Out of its two shafts one of the shaft will be connected to wheel, other will be connected to the position encoder.

Fig: Dual Shaft DC motor

Features

Working voltage : 3V to 9V
30gm weight
Ability to operate with minimum or no lubrication, due to inherent lubricity.
1.9Kgf.cm torque
Its No-load current = 60mA & Stall current = 700mA

Trigger:

The trigger is one of the important components for this mechanism as its name indicates it triggers the grenade/launch it. It can be controlled autonomously or manually. The following trigger shown is based on a real prototype.

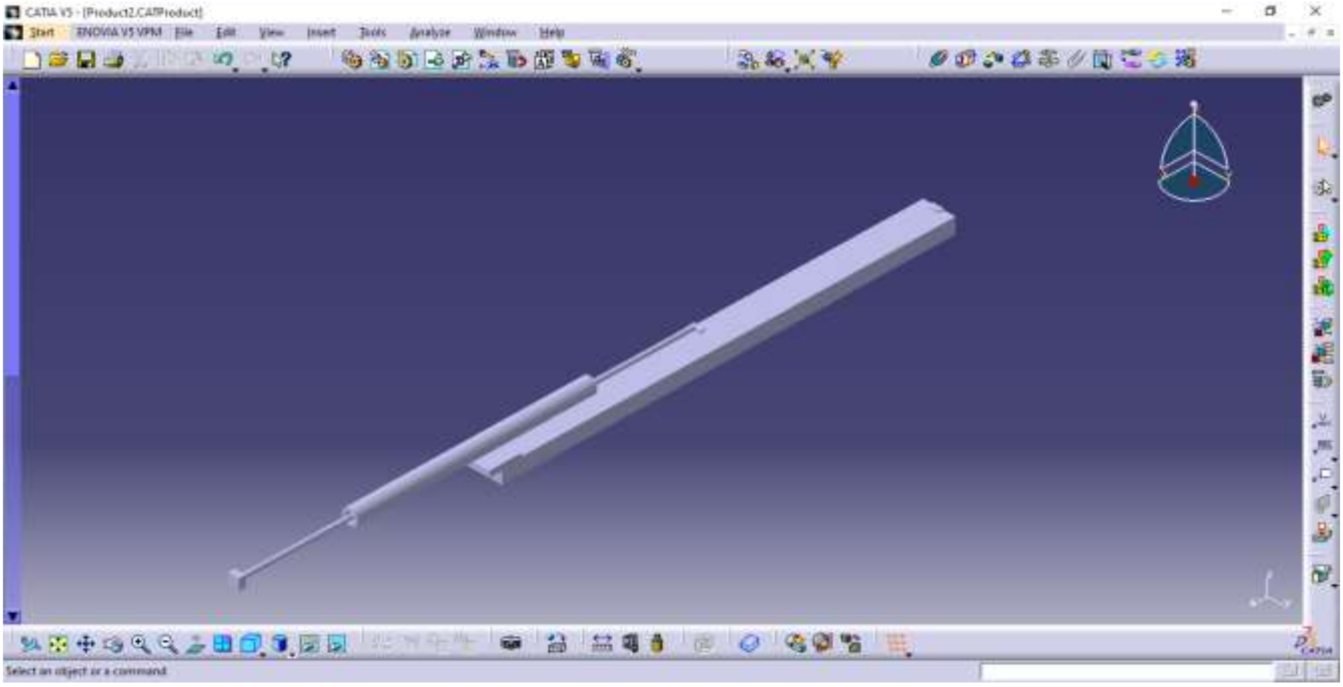


Fig: Trigger.

Working principle:

The working principle of this system is very simple, before the mission starts the teargas grenades are placed in the slots. When the drone reaches to the targeted area the Dual Shaft DC motor is activated manually or autonomously, the Dual Shaft DC motor starts to rotate the cylinder, as the cylinder starts to rotate, as will as the DC motor has some attachment added to it which hits the trigger, the trigger will launch the teargas Grenade and bush it out from its housing.

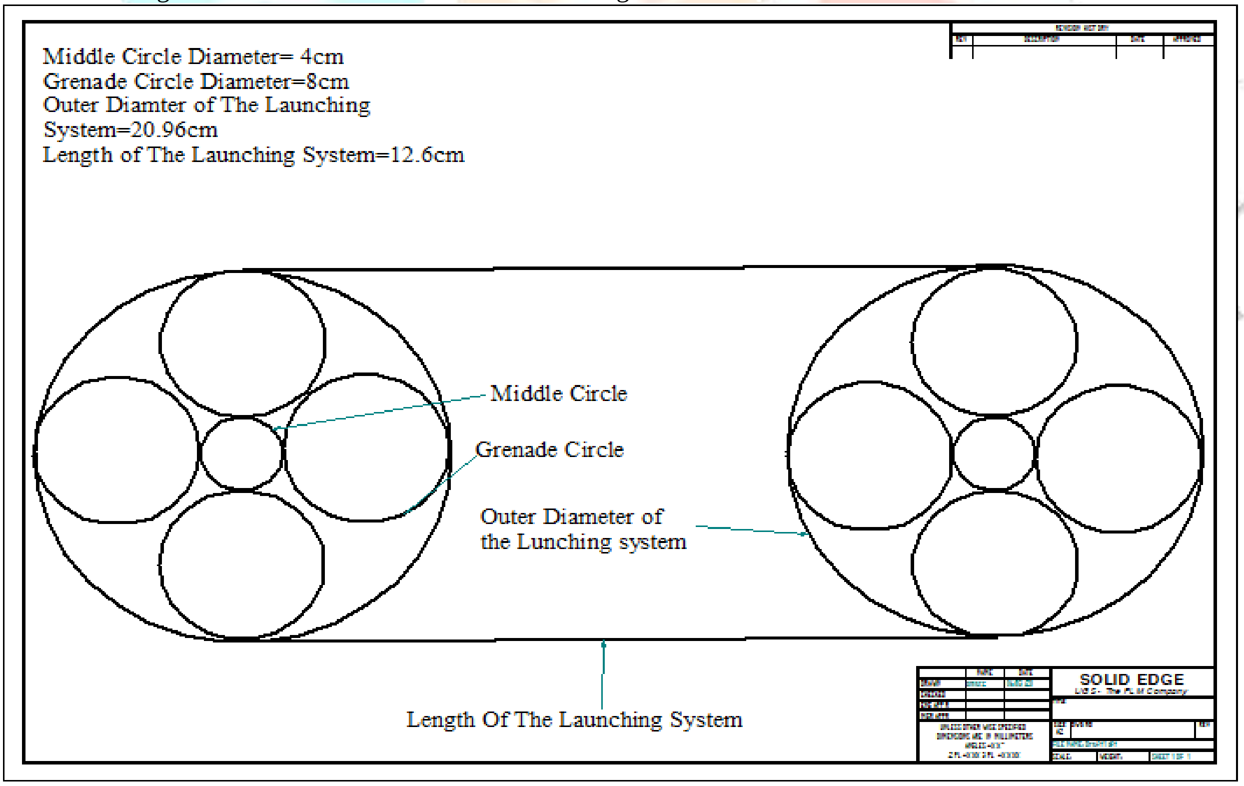


Fig: 2D drawing of Teargas Launching System.

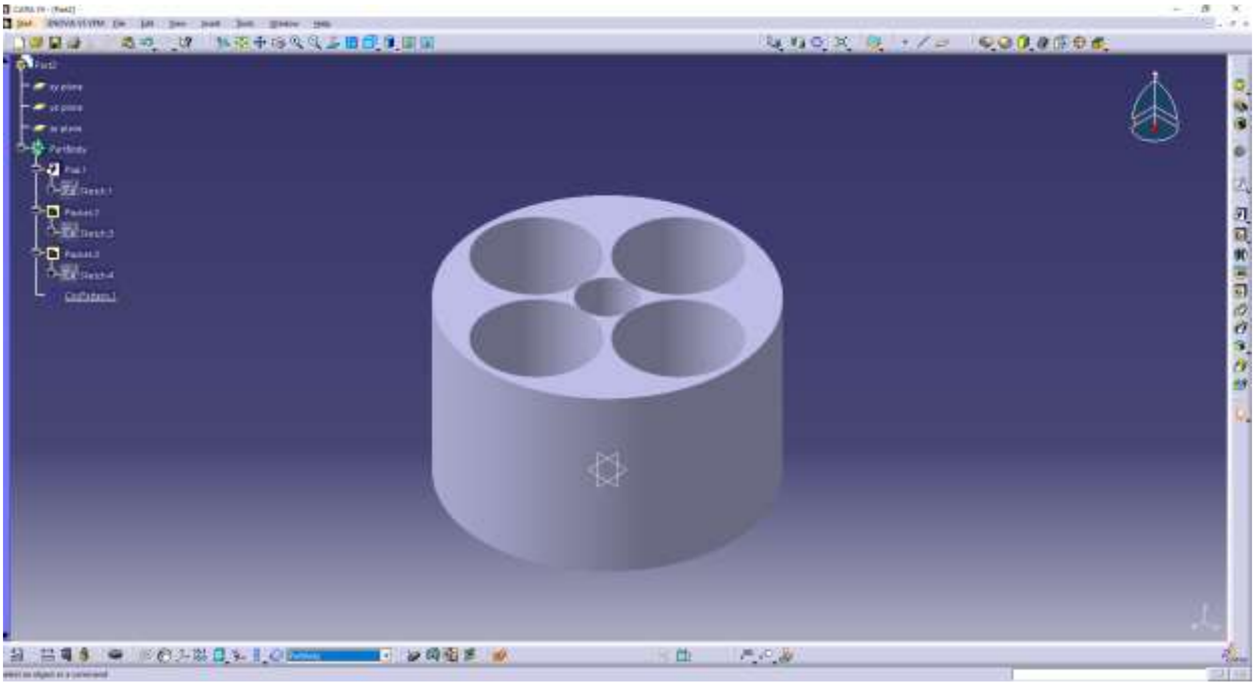


Fig: 3D drawing Teargas Launching System.

DESIGN SPECIFICATIONS

COMPONENTS	SPECIFICATION
Propeller	8 inch Plastic Propellers
Motor	Brushless D.C 600 KV motor
Flight Controller	NAZA M-lite flight controller
Electronic speed controller (ESC)	40 Ah ESC
Radio transmitter	Radio Control transmitter with eight channels
Battery	4 cell Li-Po battery, Estimated time of flight: 8 min for Foam board frame 6 min for ACP frame
Charger	4 cell battery charger, wireless charging supported

*Weight Calculation:
Total weight of the drone=4000gm
Minimum amount of thrust (2w) = 2*4000=8000 gm
Add 20% of thrust for safety of factor (sof)= 8000*20%= 8000+1600=9600gm
Divide total thrust to the number of motors= 9600/6= 1600gm
Total thrust for each motor 600kv= 1600gm
Weight of payload (camera, drop system, wireless charging coil) = 1200gm
Weight of propellers= 100*6=600gm
Weight of motors 600kv = 600gm
Weight of battery 6000 mAh 4cell=600gm
Weight of the frame= 500gm
Weight of otherpayloads (ECS, GPS, Motherboard, Receiver, etc….) =900gm
TOTAL WEIGHT= 4000gm=4kg (approximate)
*For Range and Endurance
Battery capacity = 10 AH
Battery discharge = 80%
Battery voltage(V) = 11V
All up weight(AUW) = 4kg
Watts to lift 1kg(P) = 170W
Average amp draw(AAD) = AUW*Power/V = 4*170/11 = 61.8
Time or Endurance = capacity*discharge/AAD = 10*0.8/61.8 = 0.129hr = 8min
Speed of Hexacopter = 25mph
Distance or Range = speed*time= 25*0.129 = 3.3 miles = 5.3 km

DETAIL DESIGN OF WIRELESS CHARGING

The wireless charging transmitter is powered from an input DC rail of 5 V to 19 V, typically it is derived from a USB port or an AC/DC power adapter.

The switched transistor bridge drives a coil and series capacitor by using two or four FETs. A resonant frequency is set internally, by means of the series capacitor. The transmitter has a coil to transfer power through electromagnetic induction. The induced power is coupled to the wireless power receiver, which has a similar coil to collect the incoming power. The receiver rectifies its power by means of the diode rectifiers and these are made of FETs to improving the efficiency. It also filters the power using ceramic output capacitors and then applies it to the battery that needs to be charged, through a linear stage or a switching regulator.

The battery kept inside the portable device receives the power and it gets charges up. The receiver will command the transmitter to adjust the charging current or voltage, and also to stop transmitting power completely when end of charge is indicated.

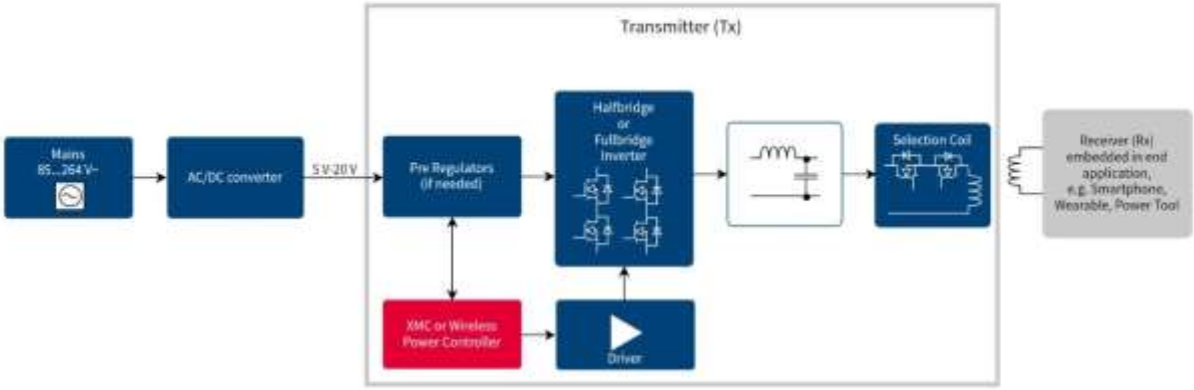


Fig: System diagram for inductive wireless charging

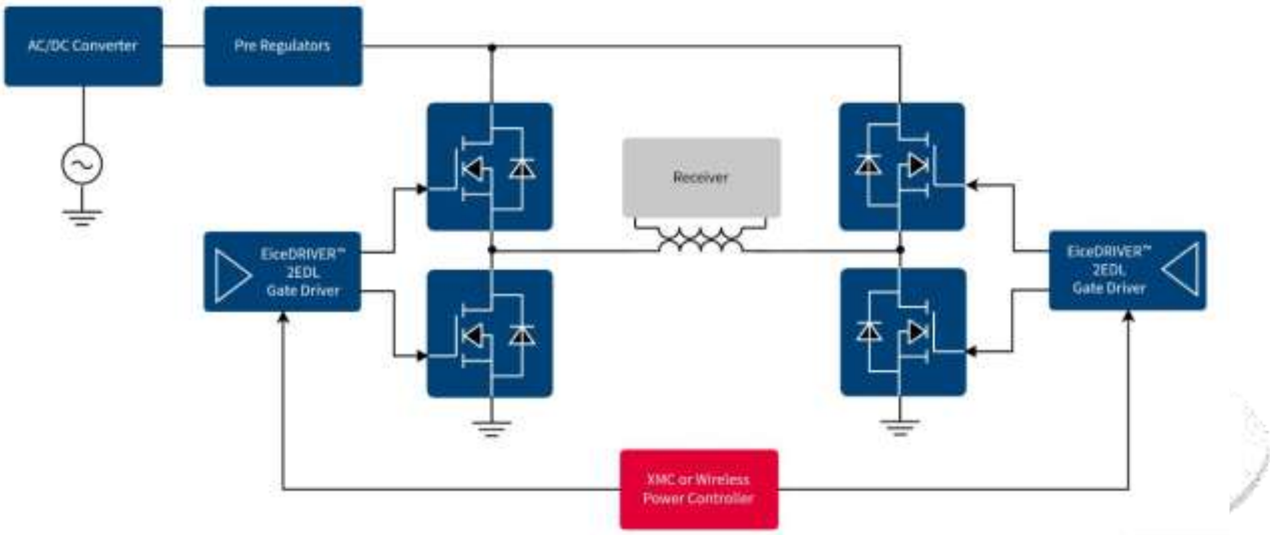


Fig:System diagram: Resonant wireless charging – class D (full-bridge or half-bridge), full bridge.

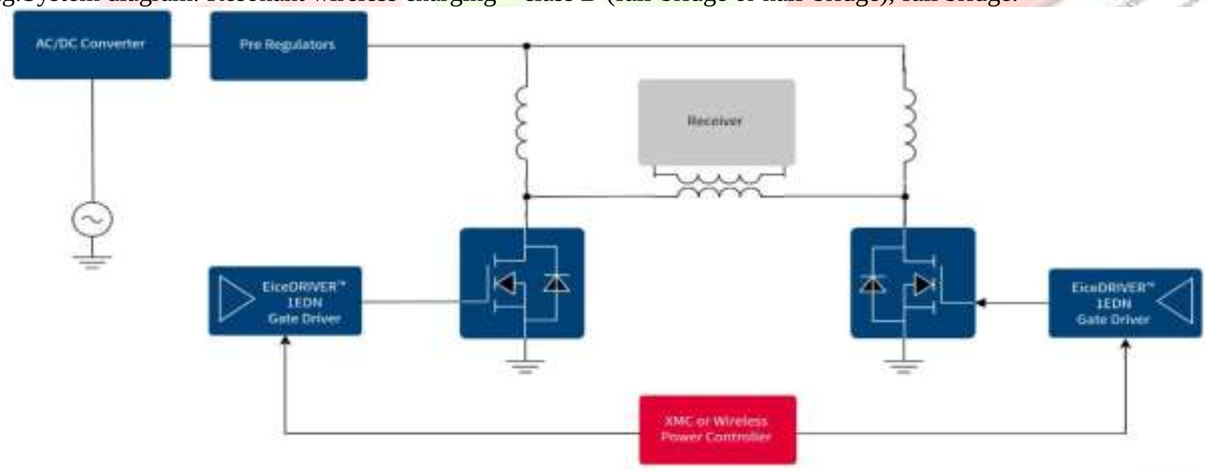


Fig:System diagram: Resonant wireless charging – class E(single-ended or differential, full bridge

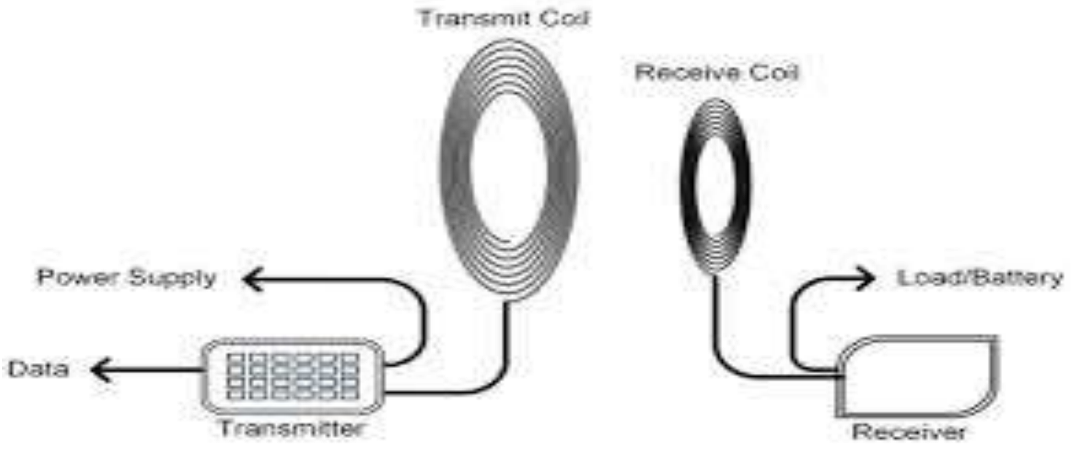


Fig: working of wireless charging.

III. RESULTS AND DISCUSSION

- The project gave us the deep knowledge on understanding of the construction of an Hexacopter.
- The performance of the Hexacopter achieves the objectives that the group had initially set out.
- The cost and efforts required by the armed forces to control the crowd and reduce the injuries and casualties from the armed forces and the protestors.
- This hexacopter is an implementation of new technology by using the dropping system of the grenades.
- There is reduction of time used for charging the battery's by using wireless charging.
- The payload fitted in this project can be replaced with any other carriage system depending on the requirement.

Fig: An overview of Hexacopter with wireless charging.

IV. CONCLUSION

Drones are not only dehumanizing war, but they are also modernizing the way countries go to war. The technologies required to build drones are some of the most advanced military technology there is, and it is being utilized to kill targeted people in wars. A large part of the dehumanization of war is due to this advanced technology, the drone, because pilots are isolated from actual battle, flying the drones, Being cut off from war lessens the impact of killing random people on a screen, just like a video game. There are many different types of drones flown by these pilots. As time goes on, drones like these will become outdated, and drones will become completely autonomous. If drones become completely autonomous, the public, which is already uncertain about the presence of drones, could be impacted in unexpected ways. Drones not only have changed the face of war, but have changed the way humans think about surveillance, impacting society on the home front as well.

For developing countries, employing helicopters and other large aircrafts for different purposes like surveillance, rescue mission, etc. is a challenge from the economic point of view. Similarly, such missions also involve great risk of human lives. As an alternative, the developed drone using the frame locally made of ACP and off-the-shelf purchased electronic parts is very stable, robust, easy to operate and maintained. After a number of successful test flights and public demonstrations, it is now fully functional and ready to take off the payload for different application as mentioned above.

V. ACKNOWLEDGEMENT

We thank Dr. S K Maharana, Professor & Head, Department of Aeronautical Engineering, Acharya Institute of Technology who have been a constant source of inspiration for us and helped us in every aspect, guiding and motivating us.

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