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MANCHESTER 1824
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Evaluation and Mitigation of Offshore HVDC Valve Hall Magnetic and Electric Field Impact on Inspection Quadcopter

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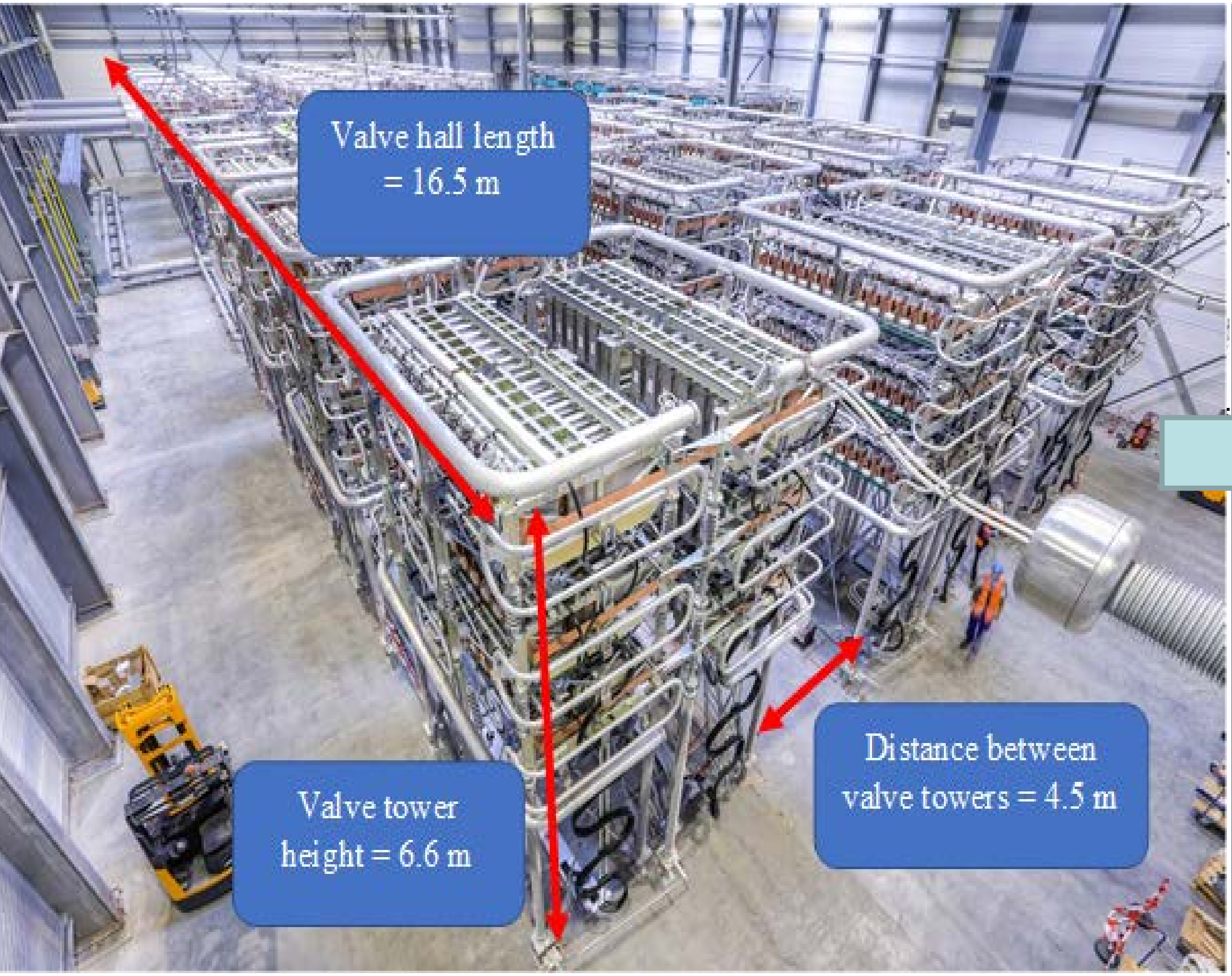
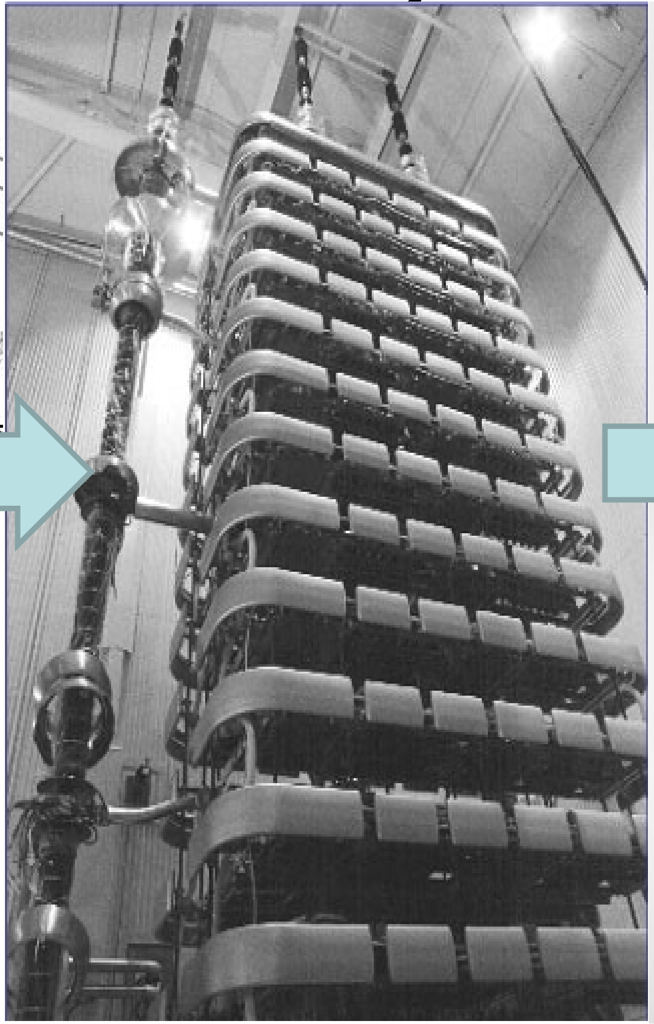
Agenda

- Valve Halls in HVDC System.
- Development in Thyristor Technology.
- An Inspection UAV for Valve Hall Monitoring.
- High Electromagnetic Field Risks Inside Valve Hall.
- High Electrostatic Field inside Valve Hall .
- Drone Electrostatic Field Testing.
- High Magnetic Field inside Valve Hall.
- Drone Magnetic Field Testing.

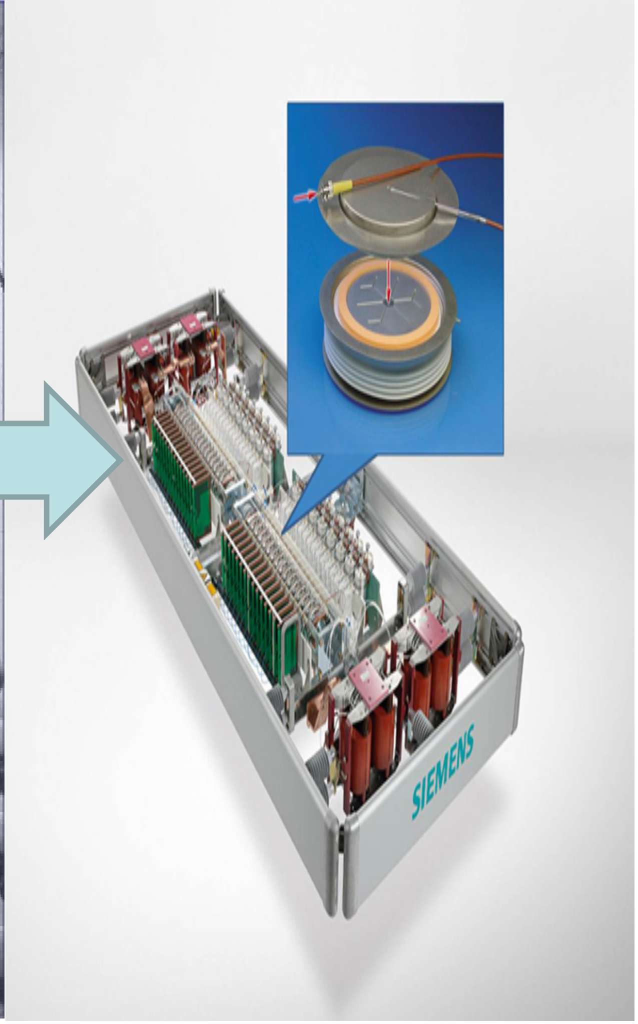
Valve Halls in HVDC System



HVDC converter platform[2]



An HVDC valve tower 16.8 m tall in a hall at Baltic Cable AB in Sweden[3]



Thyristor Module[4]

An Inspection UAV for Valve Hall Monitoring

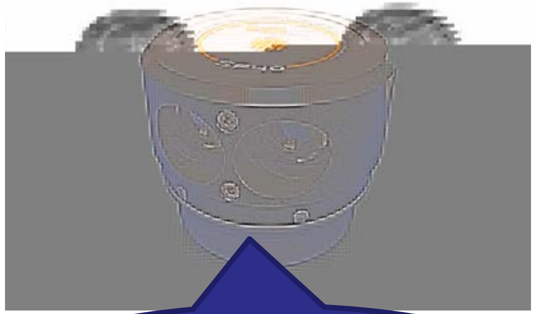
- We propose an off-shelf drone in which we have integrated number of sensors for indoor monitoring inside the valve hall.

Dual Camera

Allows visible light and thermal images at the same time

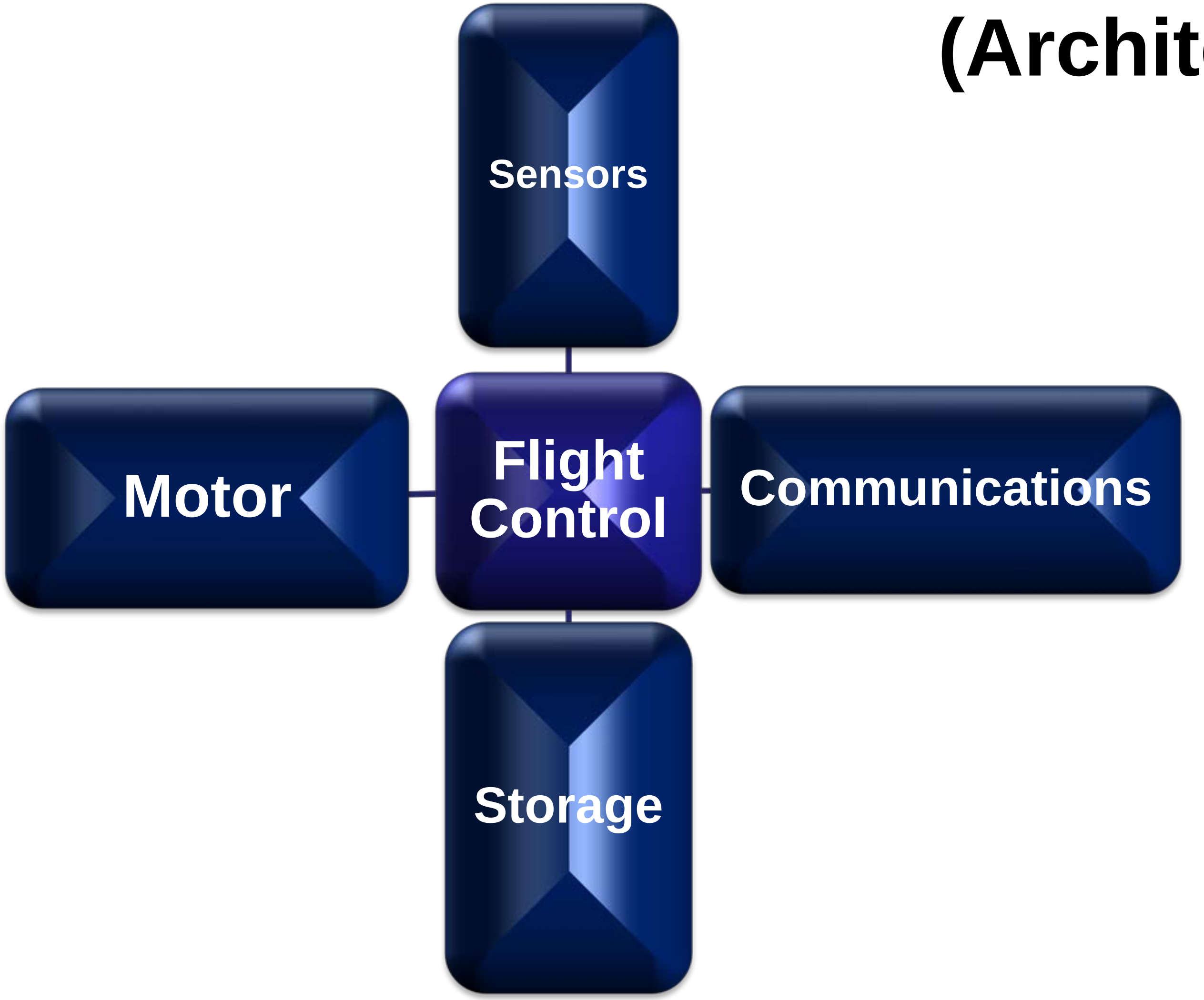
Proposed Drone

LiDAR



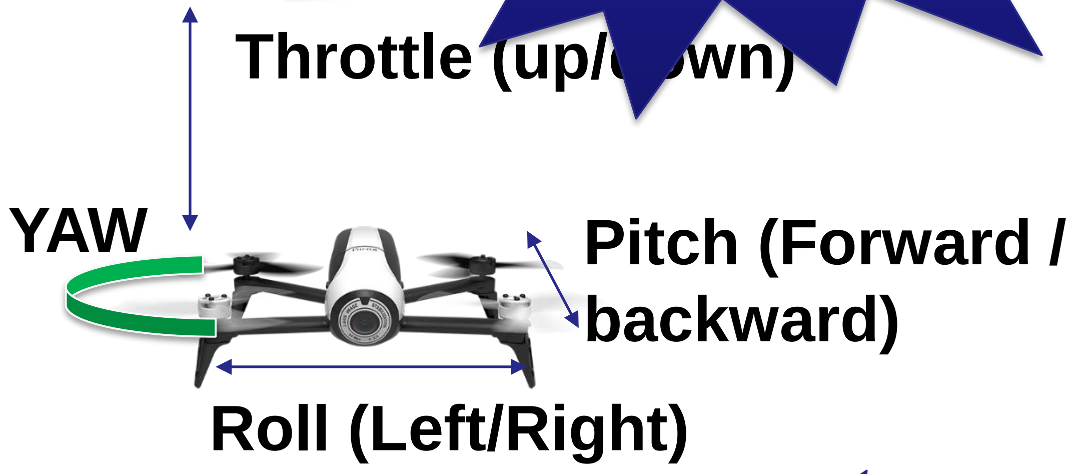
2D mapping and navigation in GPS denied environment

An Inspection UAV for Valve Hall Monitoring (Architecture)



Drone Architecture Modules

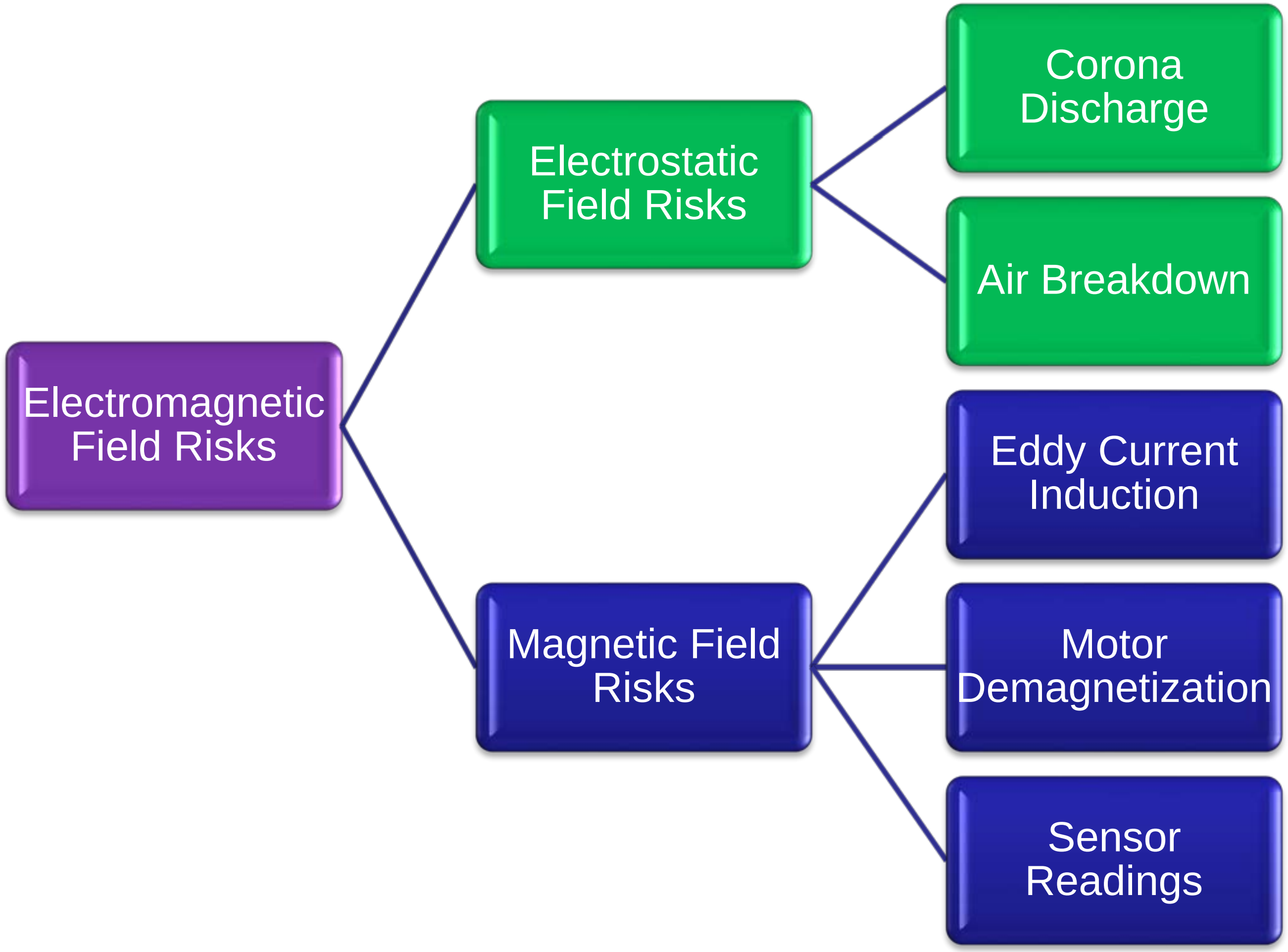
Is there a problem in navigating a drone inside a valve hall?



Drone N igation Co l Char

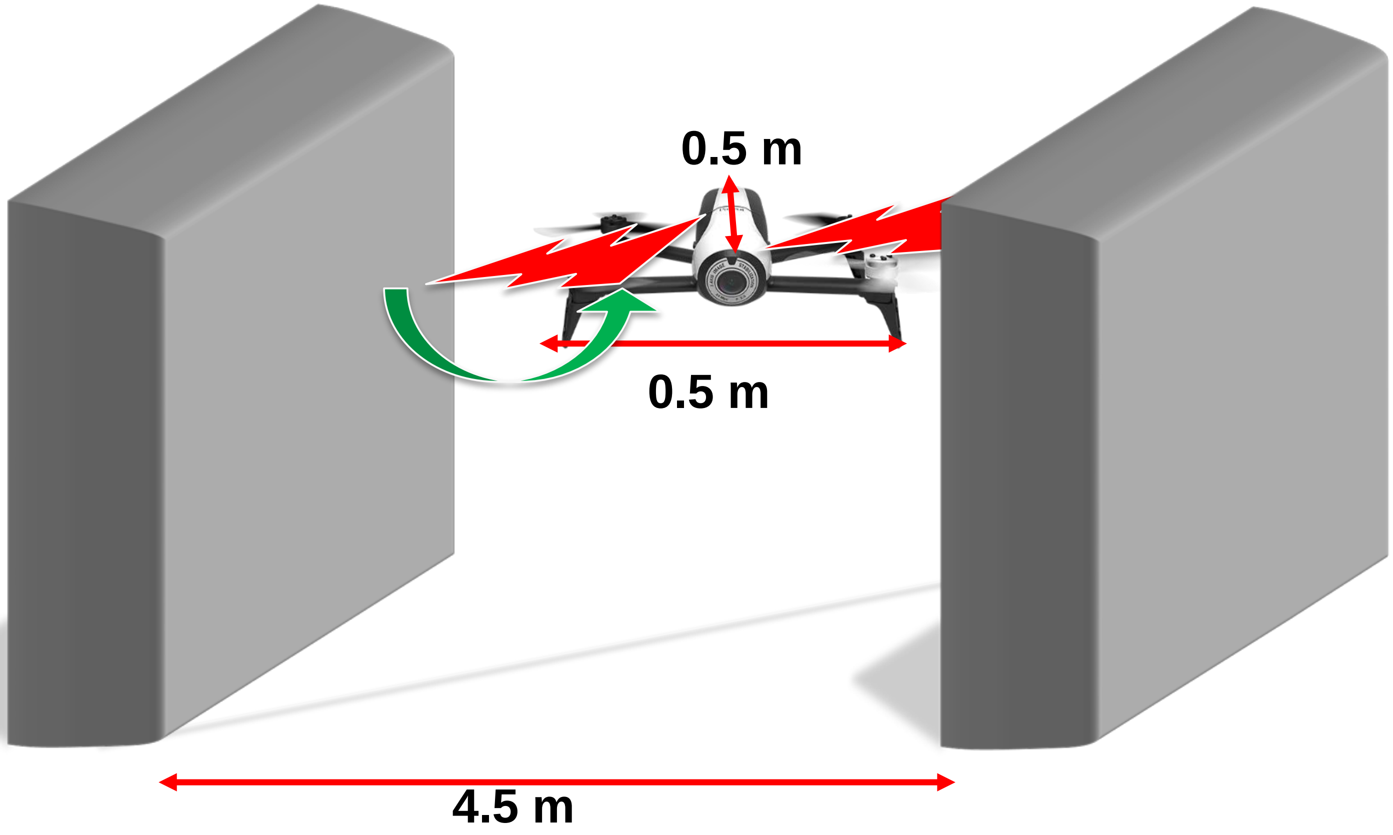
How can we guarantee normal operation of the drone in a valve hall?

High Electromagnetic Field Risks Inside Valve Hall



High Electrostatic Field inside Valve Hall (Risks)

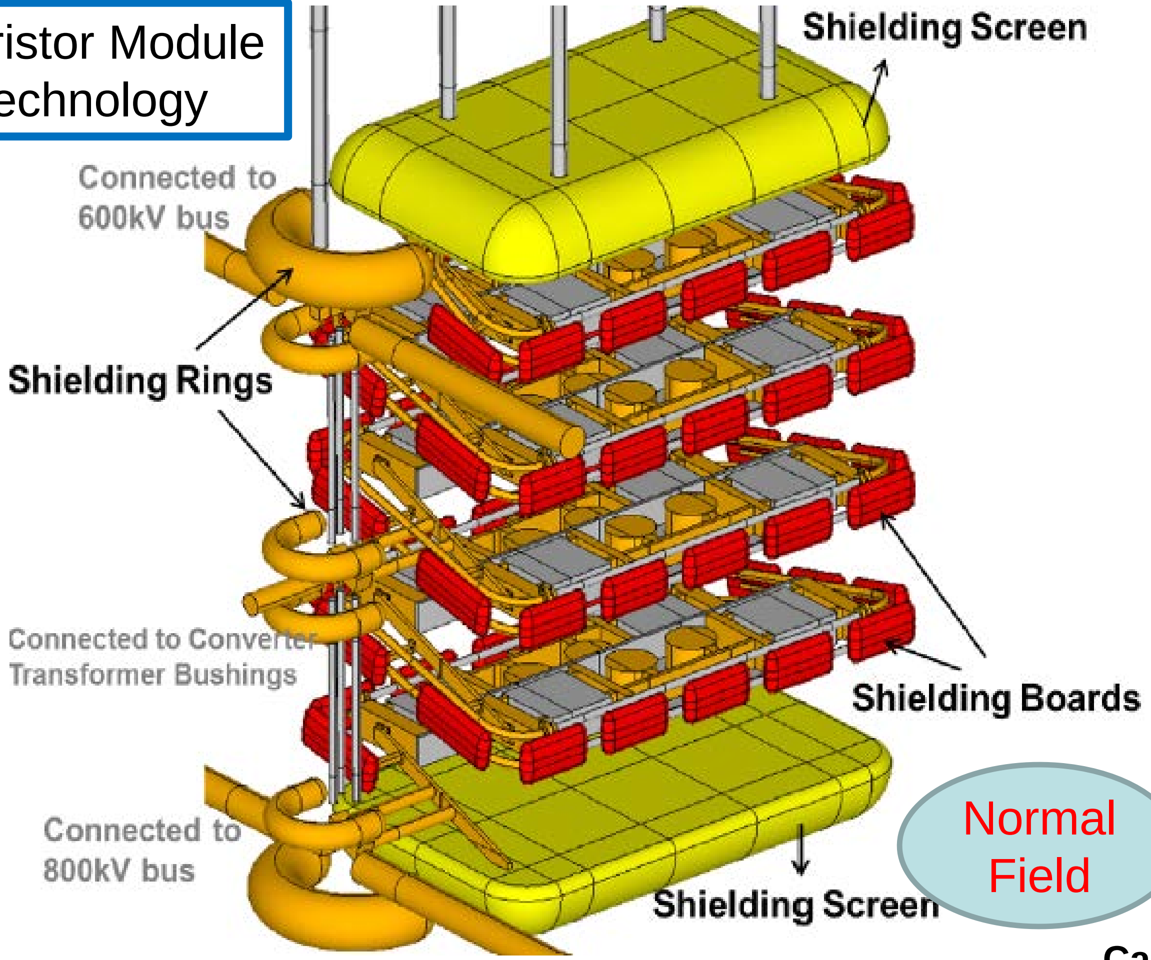
- High voltages inside the valve hall creates high electrostatic field which implies two main risks:
  - Corona Discharge current from a stack to the drone.
    - ~ 2000V/mm
  - Air Breakdown or Flashover between 2 stacks.
    - ~ 3000V/mm



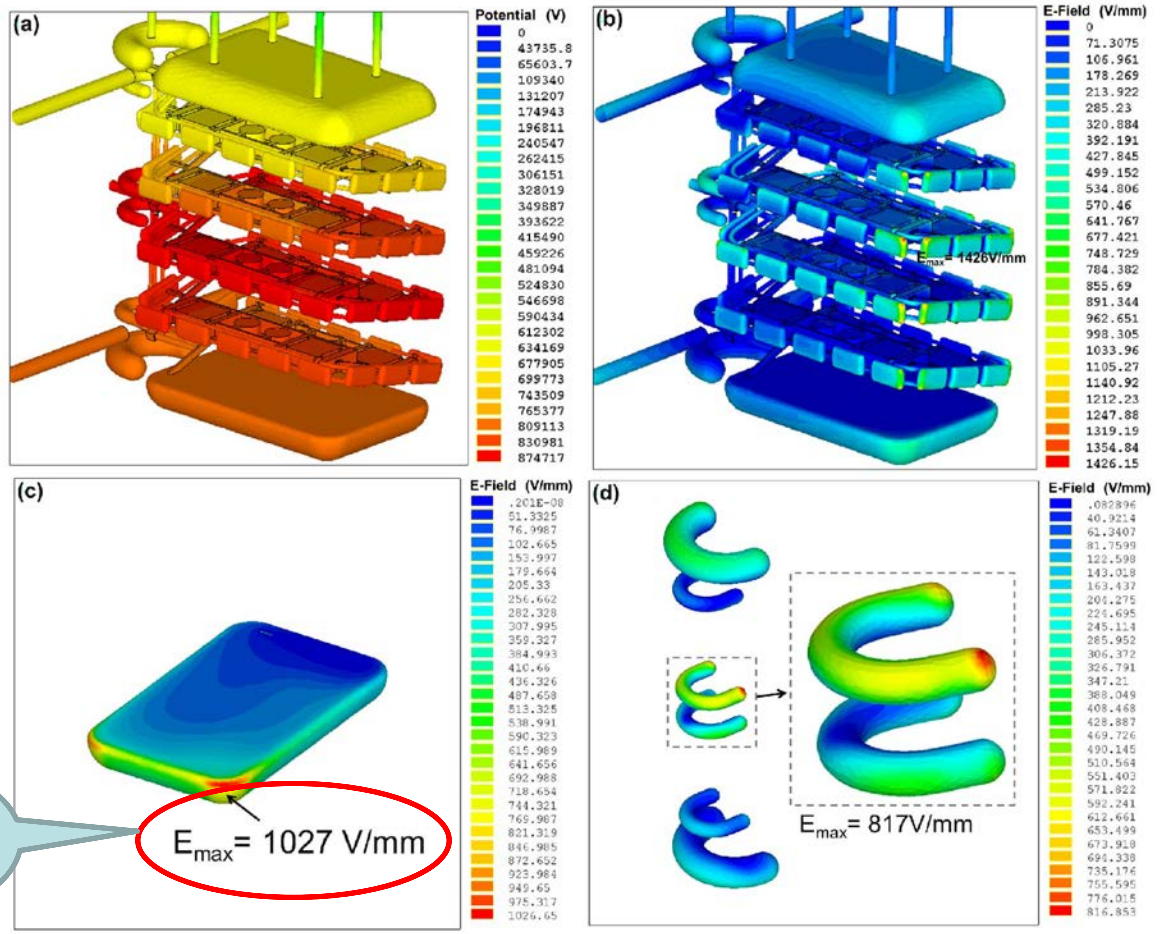
Electrostatic risks inside a valve hall

High Electrostatic Field inside Valve Hall (Evaluation)

Thyristor Module Technology



Model of typical double valve used in the high voltage valve hall of ±800kV UHVDC converter station[7]



Calculation results of double valve (a) potential distribution (b) the whole E-field distribution (c) E-field distribution on shielding screens (d) E-field distribution on shielding rings[7]

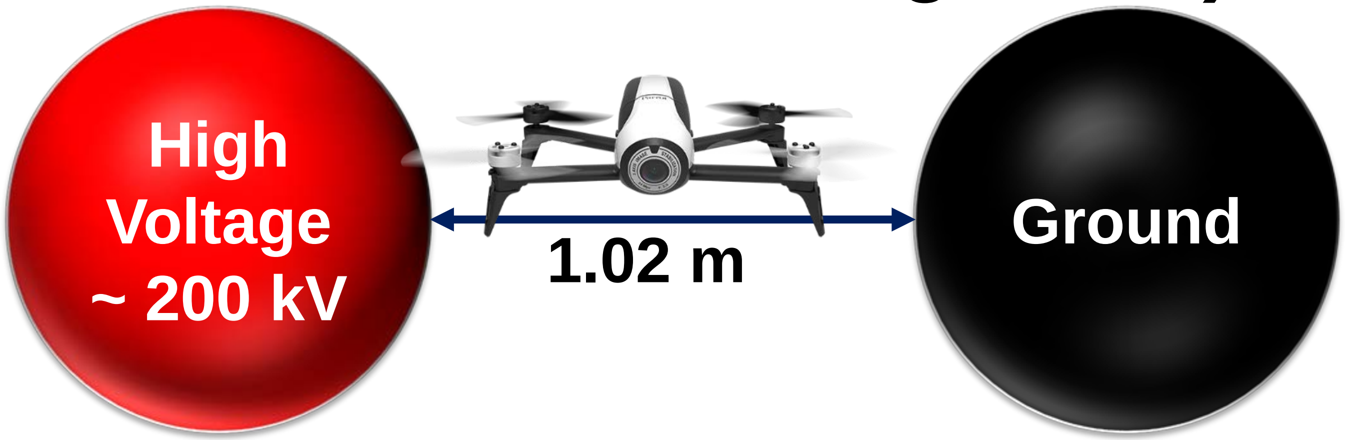
High Electrostatic Field inside Valve Hall (Evaluation)

- As shown in previous figure, the electric field in the normal conditions can reach to 1027 V/mm.

- Q1: What happens if the electric field exceeds these values in case of faulty conditions? Could our drone help investigating these critical cases?

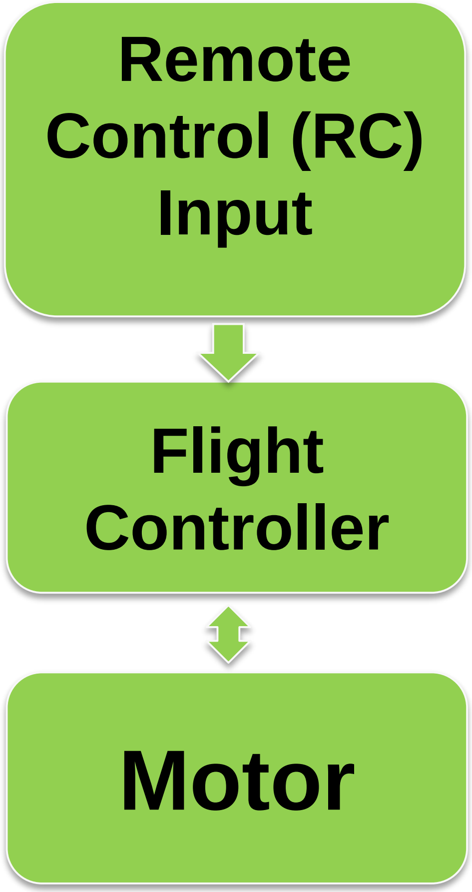
- Q2: Can the drone sustain normal operation in high electric field values in the range from 1000 V/mm to 2000 V/mm?

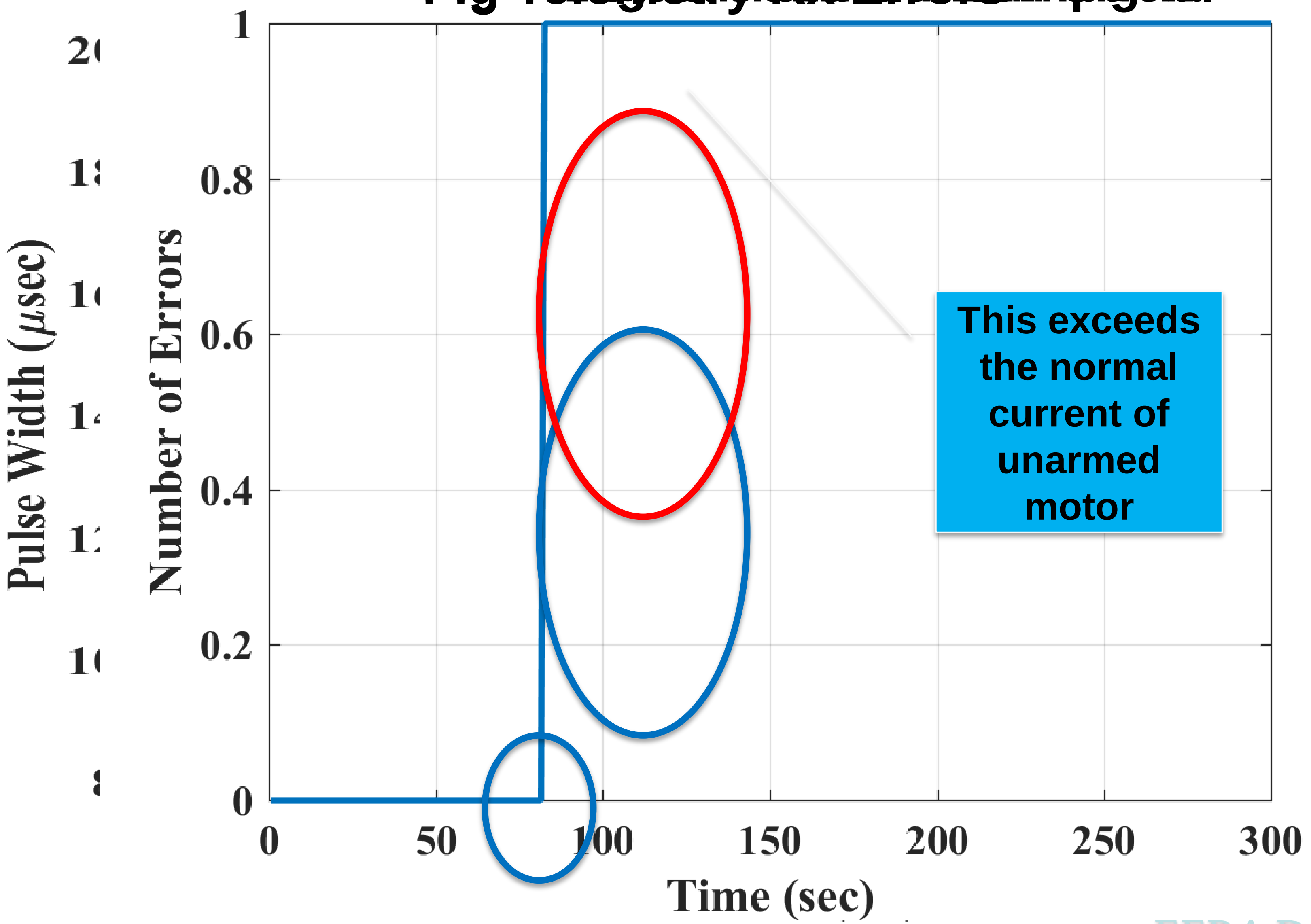
Drone Electrostatic Field Testing (Exp. (1) Corona Discharge Risk)



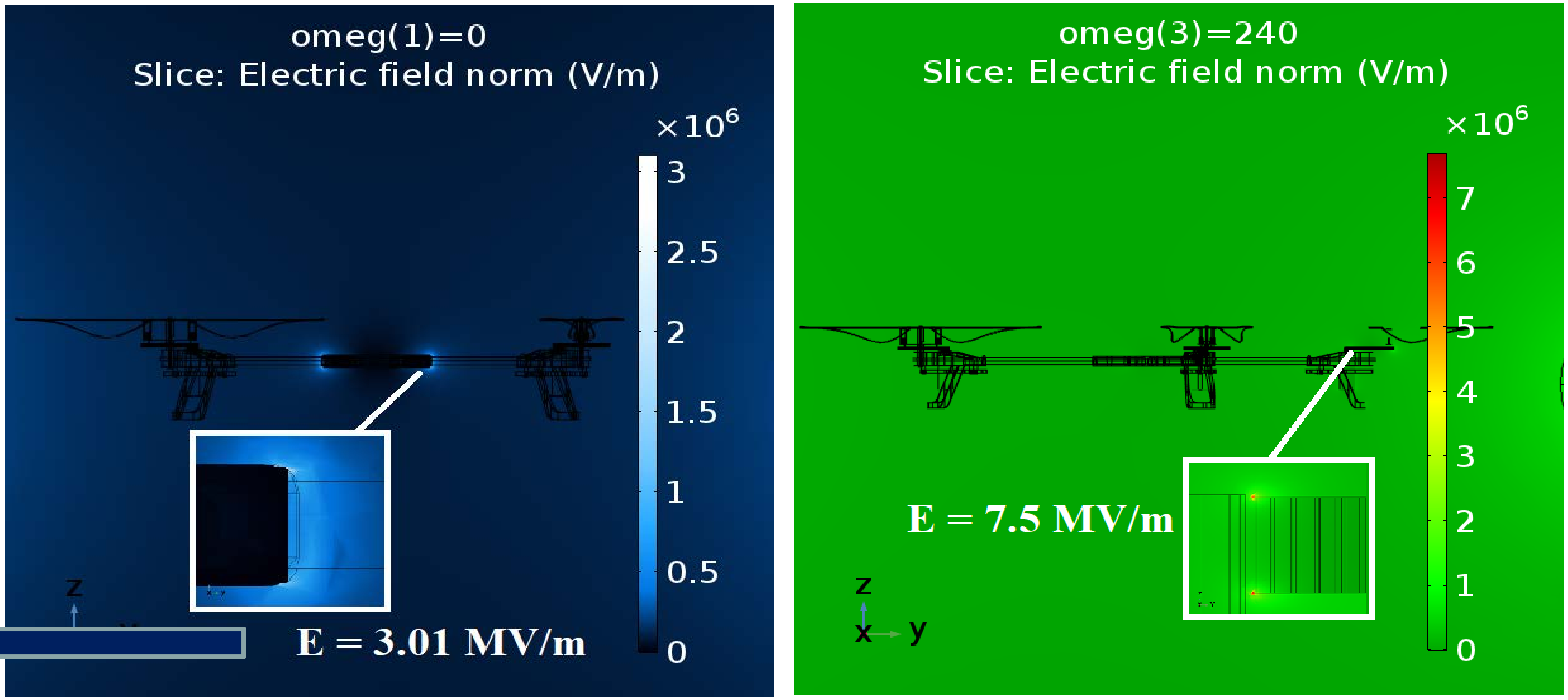
Exp. (1) setup for testing corona discharge current effect

- Aim: Finding the effect of the corona discharge current on the drone.
- The drone is inserted, and 100 kV voltage is applied with increasing step of 20 kV.
- Obs.: The motors of the drone stopped working after **200 kV** and do not return back to normal operation until the drone is manually restarted.


Remote Control (RC) Input
Flight Controller
Motor


Pulse Width (μsec)
Number of Errors
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
Time (sec)
This exceeds the normal current of unarmed motor

Drone Electrostatic Field Simulations (Corona Discharge Risk)



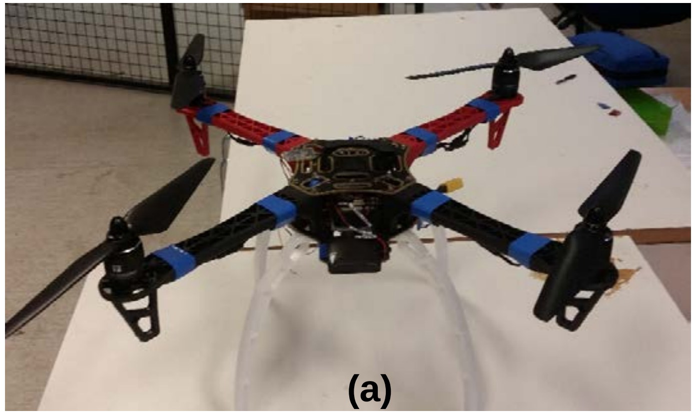
(a) (b)

Electrostatic field distribution on the drone for (a) Autopilot Section, and (b) Actuation Section

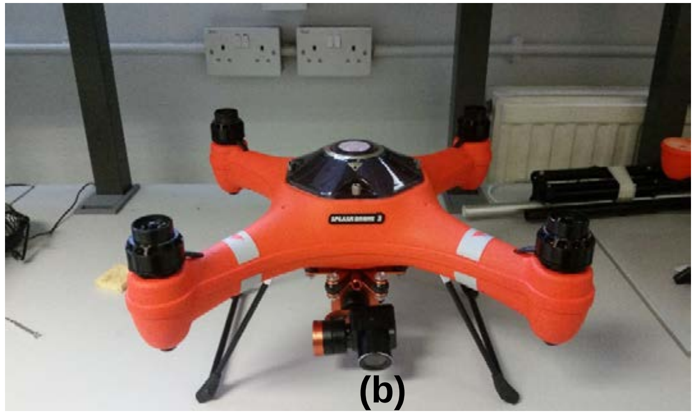
Corona discharge emission excitation

Drone Electrostatic Field Testing (Exp. (1) Conc.)

- The corona discharge current can affect different drone modules like communication module and motor controller module.
- For a drone to avoid interference from corona discharge current, it should be shielded.
- However, this raises another question: Could this shielding cause any flashover?



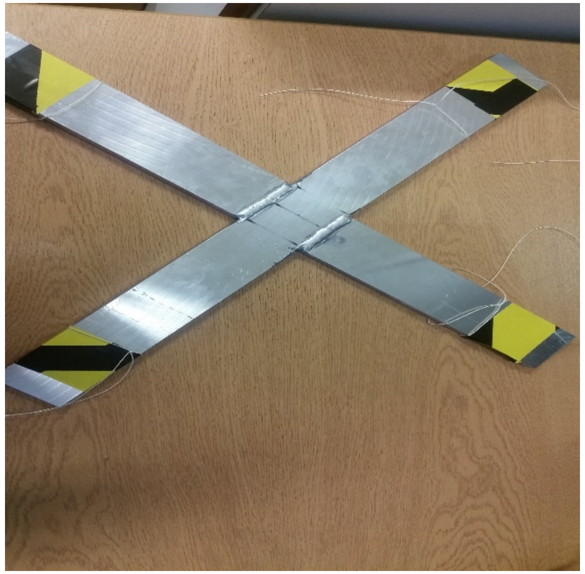
(a)



(b)

Drone Model (a) Unshielded (b) Shielded

Drone Electrostatic Field Testing (Exp. (2) Flashover Risk)



(a) UAV Cross Bar Model

(b) Air Breakdown

Tethered UAV model between HV end and the ground

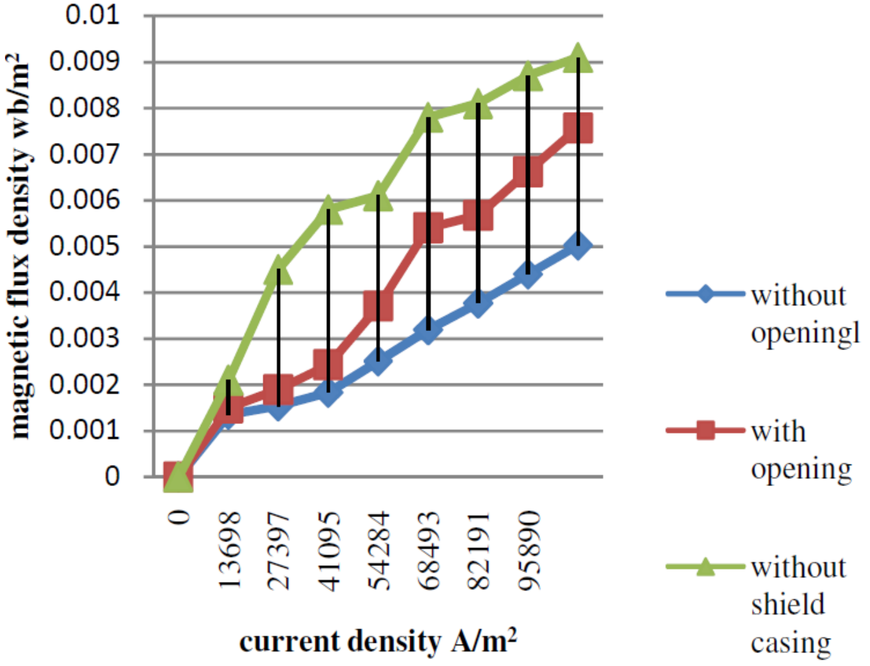
- Aim: Find the effect of navigating a shielded drone inside a valve hall on changing air breakdown characteristics regarding clearance distances.
- A complete metal cross bar (UAV model) was tethered between HV end (*i.e.* ~ 1.1 MV) and the ground.
- Obs.: The breakdown voltage is decreased by 5 % only in the case of negative impulse test and no change at all in the case of positive impulse test.

Drone Electrostatic Field Testing (Conclusions)

- Navigation of an inspection drone inside the high electrostatic field of HVDC valve halls can cause corona discharge current interference to different drone parts.
- A complete shielding solution is recommended to avoid corona discharge current interference.
- The shielding solution has a limited effect on changing air breakdown clearances inside the valve hall.

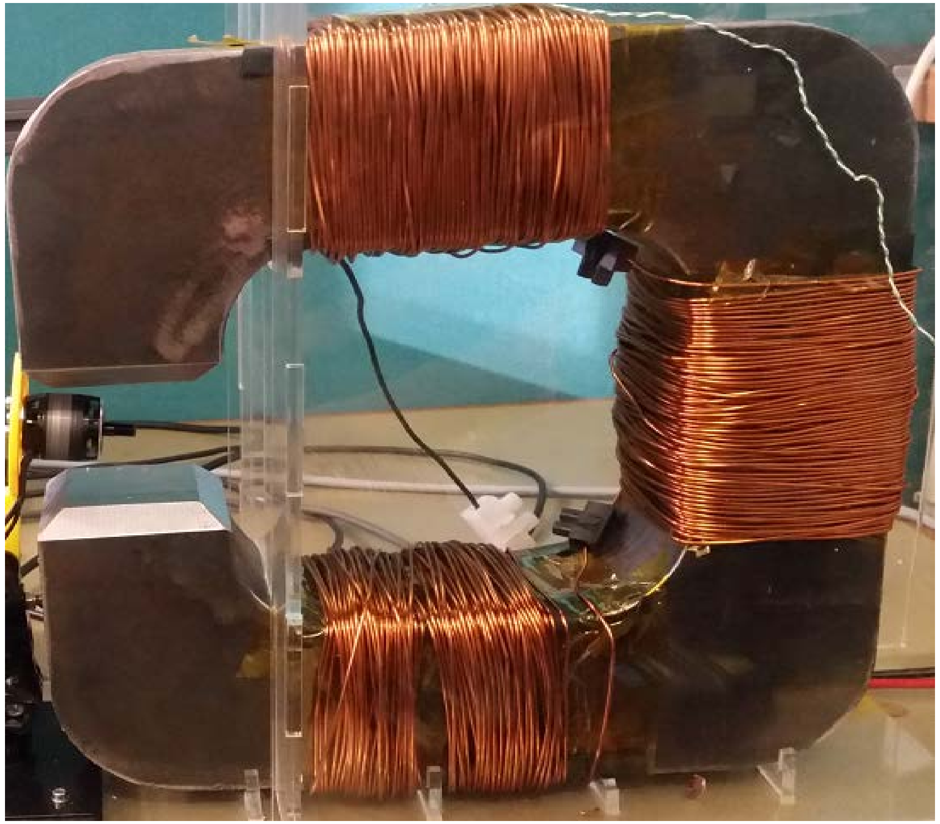
High Magnetic Field inside Valve Hall (Evaluation)

- The thyristor inside valve hall is rated for high currents (> 4000 A), which induce high magnetic field.
- In [9], the magnetic field is reported for a valve equipped with 182.5 cm^2 thyristor for a current range between 0 A and 4000 A.
- Shielding of valves can decrease the magnetic field from 9 mT to 5 mT, which still can affect the drone navigation.



Flux densities at different current densities and different shielding mechanisms[9]

Drone Magnetic Field Testing (Setup)



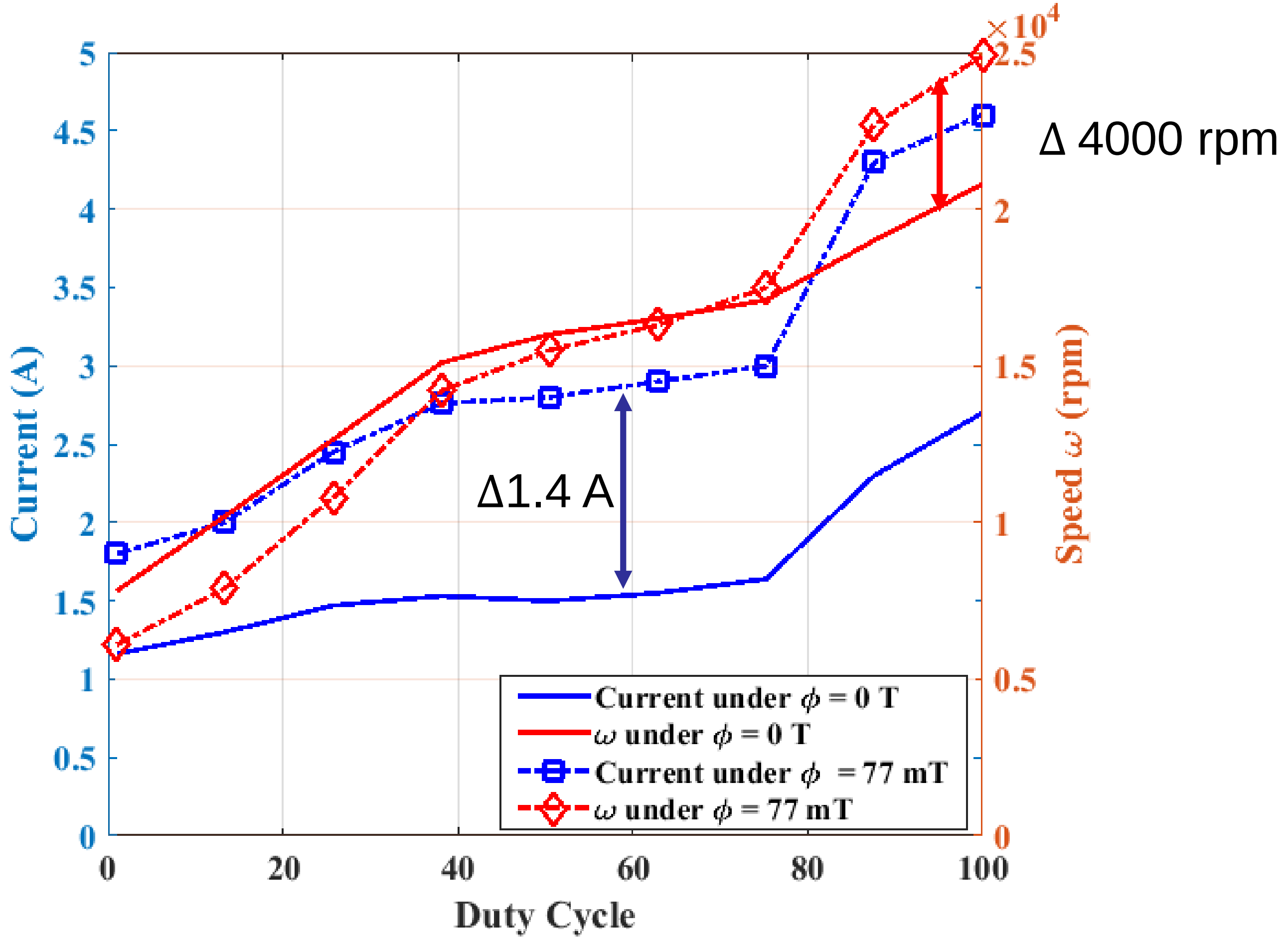
Magnetic Field Test rig

Motor 1

Motor 2

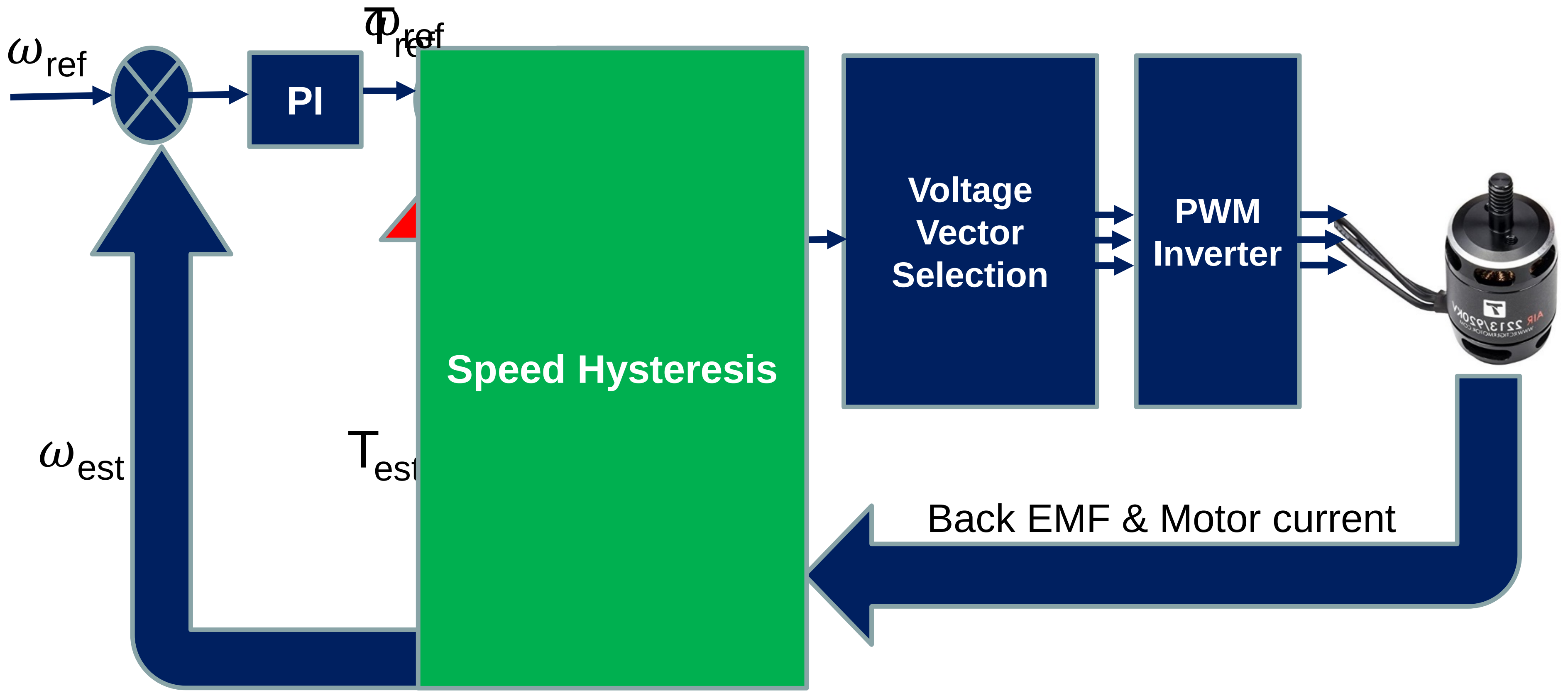
Motor 3

Drone Magnetic Field Testing (Results)



Motor Current and speed in presence/absence of magnetic field

Drone Magnetic Field Testing (Analysis)



Direct torque control in the drone ESC

Drone Magnetic Field Testing (Conclusion)

- Valve hall magnetic field can influence nominal operation of the drone motors, which are controlled using off-shelf speed controllers.
- Current speed controllers use torque control algorithm to operate drone motors, which is proved to be inefficient in the presence of high magnetic field.
- Special design for speed controllers is recommended, which uses the velocity control algorithm to operate the drone motors.

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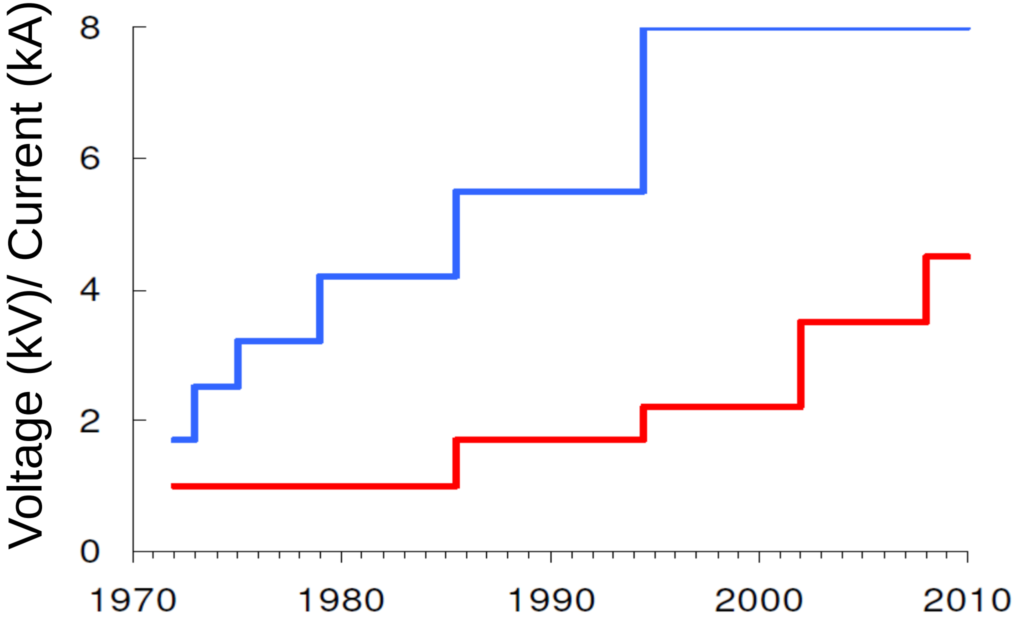
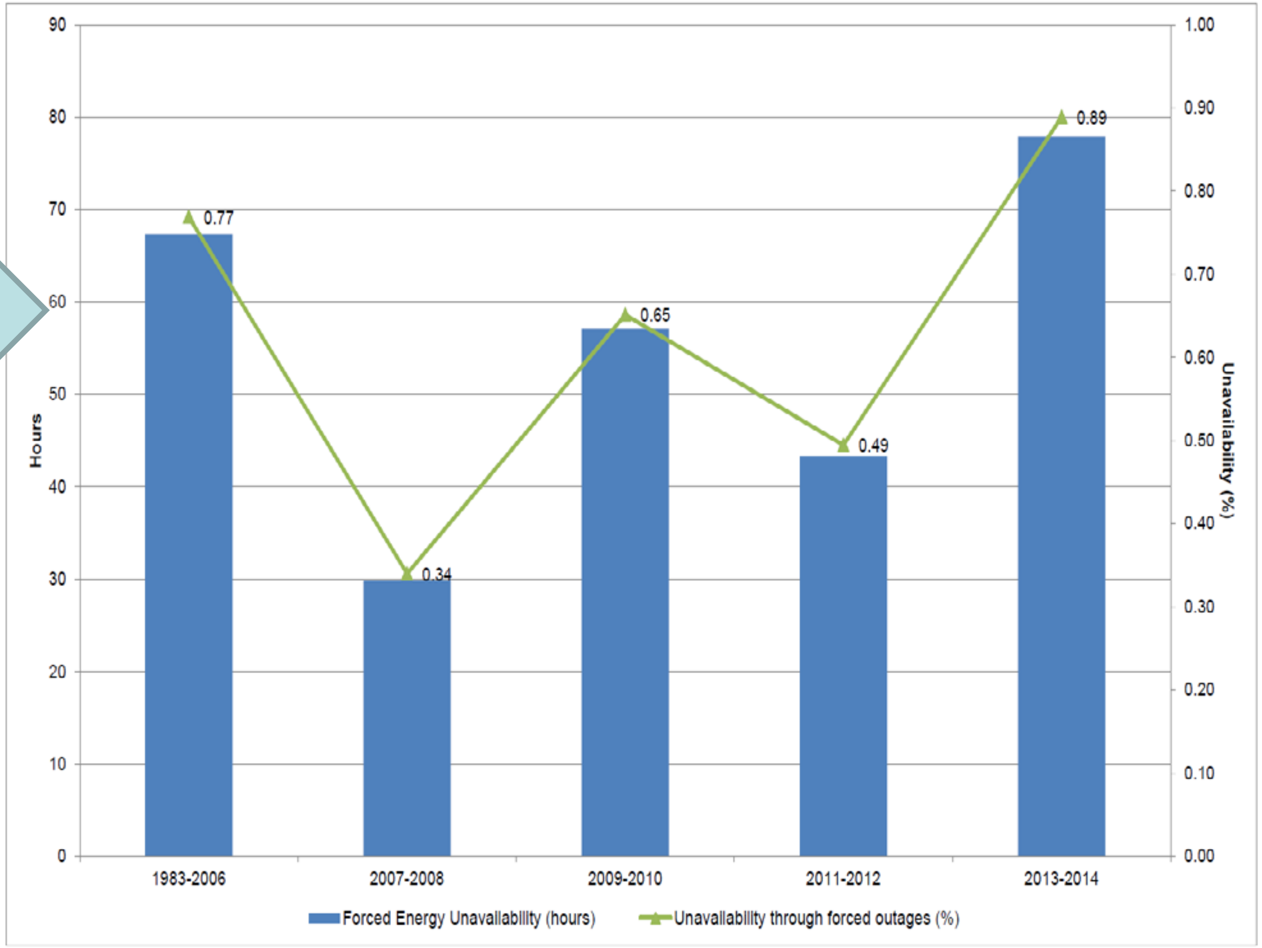
Thank you

Questions?

Development in Thyristor Technology



Development of voltage rating (blue line) in kV and current rating (red line) in kA of power thyristors[5]



HVDC Converter Unavailability[6]

- Thyristors had developed in the last years in terms of rated power.
- This development should be accompanied with good monitoring services to maintain system stability.

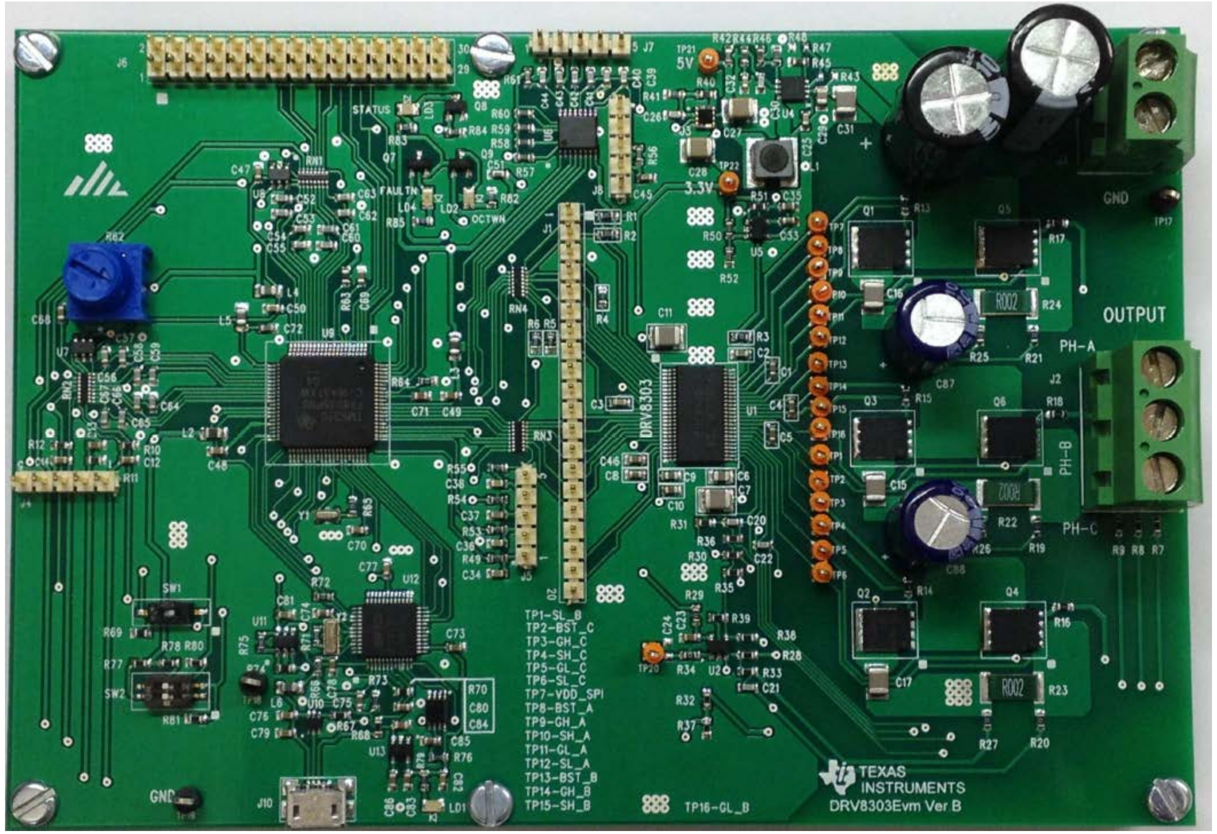
Drone Electrostatic Field Testing (Future Work)

- Conducting both AC and DC field corona tests to evaluate the drone shield immunity against high electrostatic field interference.

Refurbished HV lab facilities at UoM

Drone Magnetic Field Testing (Future Work)

- Implementation & testing of velocity control algorithm to mitigate high magnetic field impact, using evaluation boards of programmable speed controllers.



Texas Instruments evaluation board DRV8303EVM

Drone Navigation in HVDC substations

- Development of autonomous navigation techniques that are viable in a dark, GPS-denied and confined environment.
- Development of computationally efficient fault identification algorithms using on-board sensors.
- Cooperation with industrial partners for field tests in real-world operational substation