

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



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WP2.2 lead



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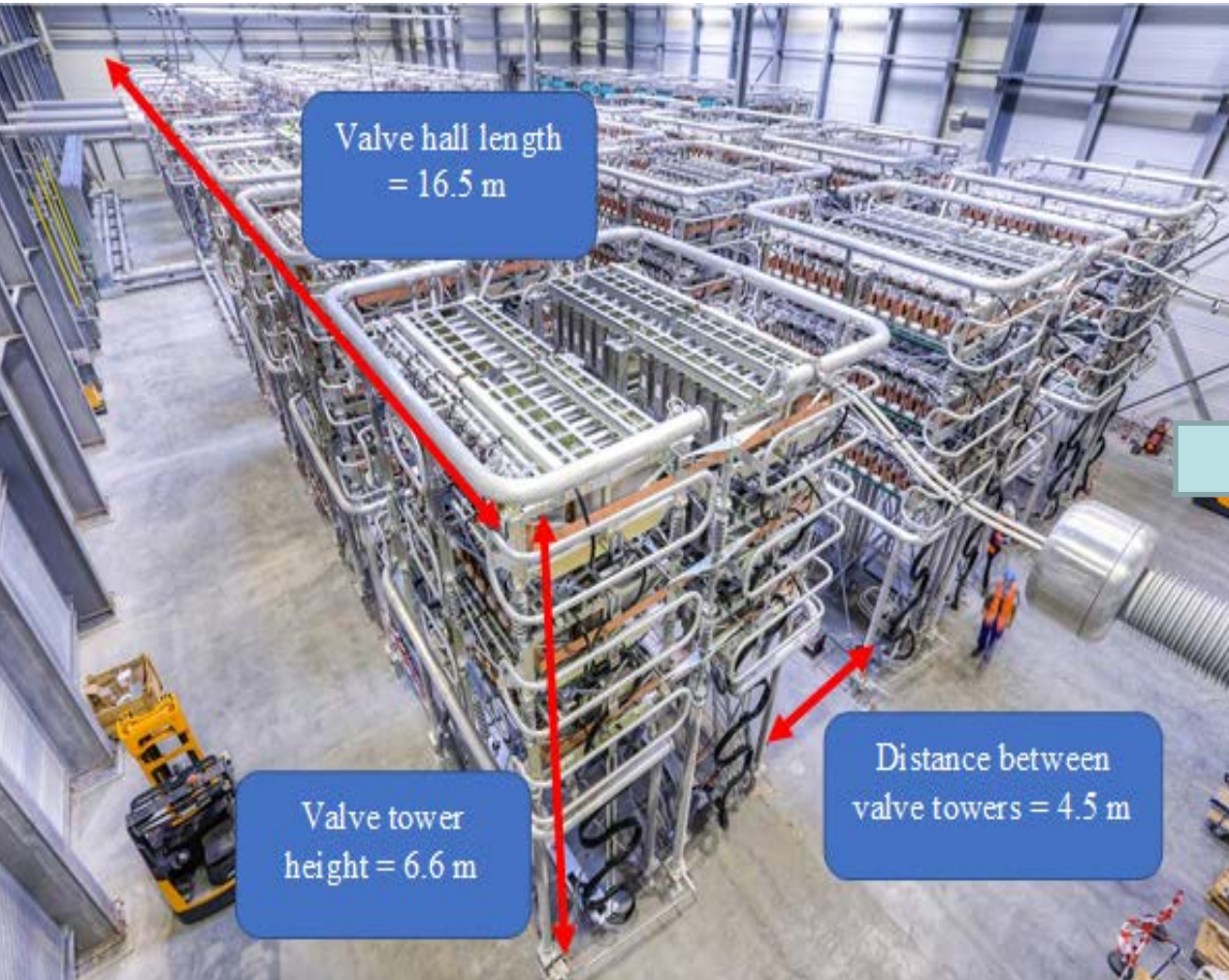
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## Agenda

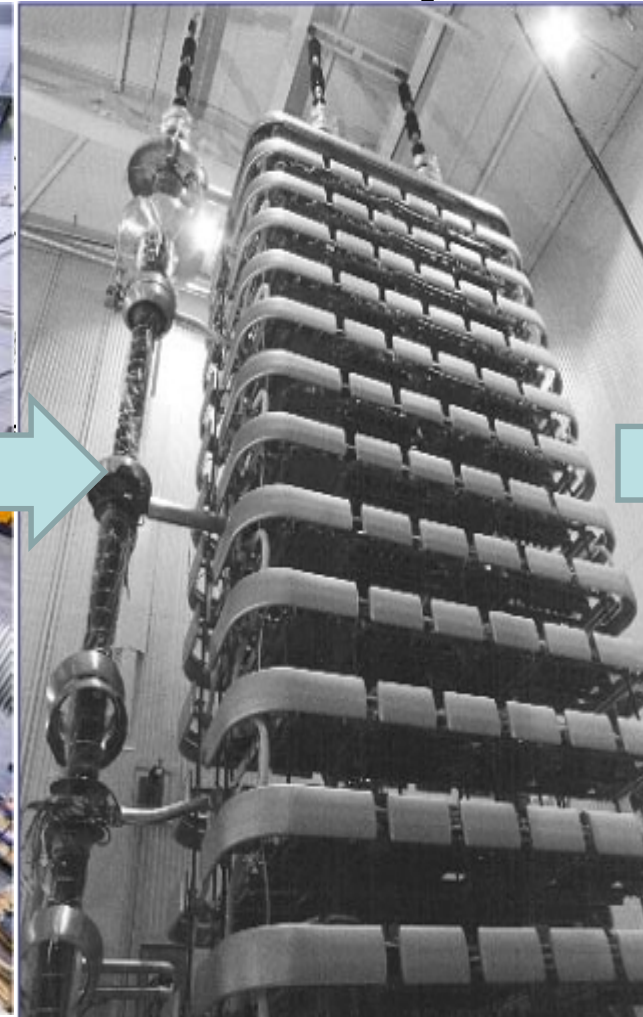
- Valve Halls in HVDC System.
- Development in Thyristor Technology.
- An Inspection UAV for Valve Hall Monitoring.
- High Electromagnetic Field Risks Inside Valve Hall.
- High Electrostatic Field inside Valve Hall .
- Drone Electrostatic Field Testing.
- High Magnetic Field inside Valve Hall.
- Drone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



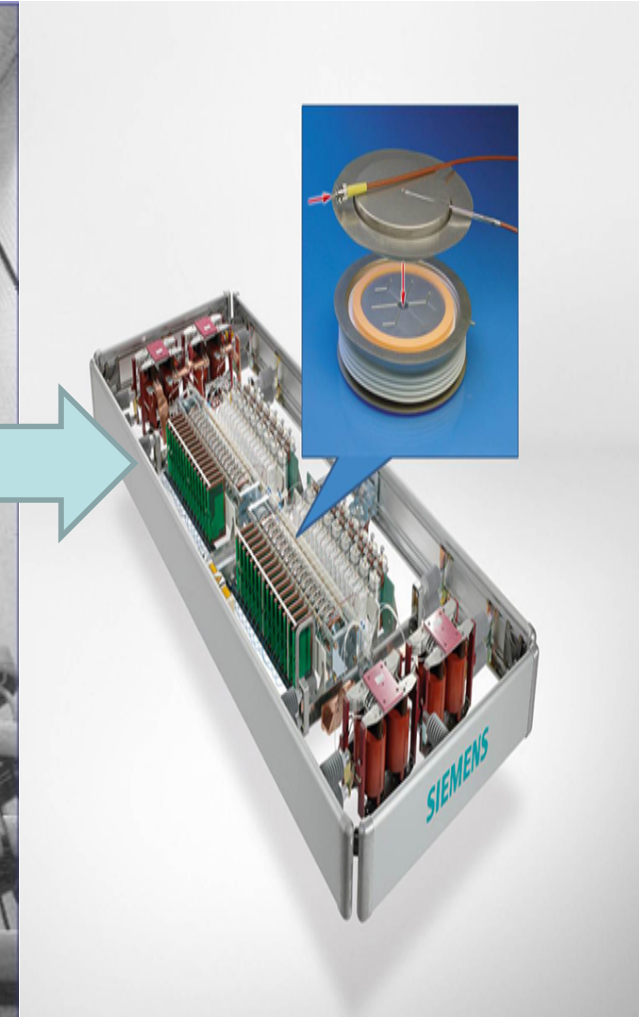
# Valve Halls in HVDC System



HVDC converter platform<sup>[2]</sup>



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



Thyristor Module<sup>[4]</sup> 3



# 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

FLIR DUO R

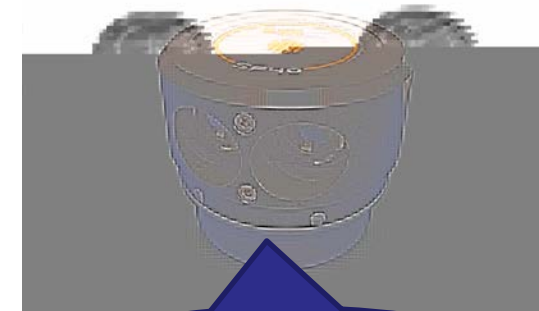


Allows visible light and thermal images at the same time



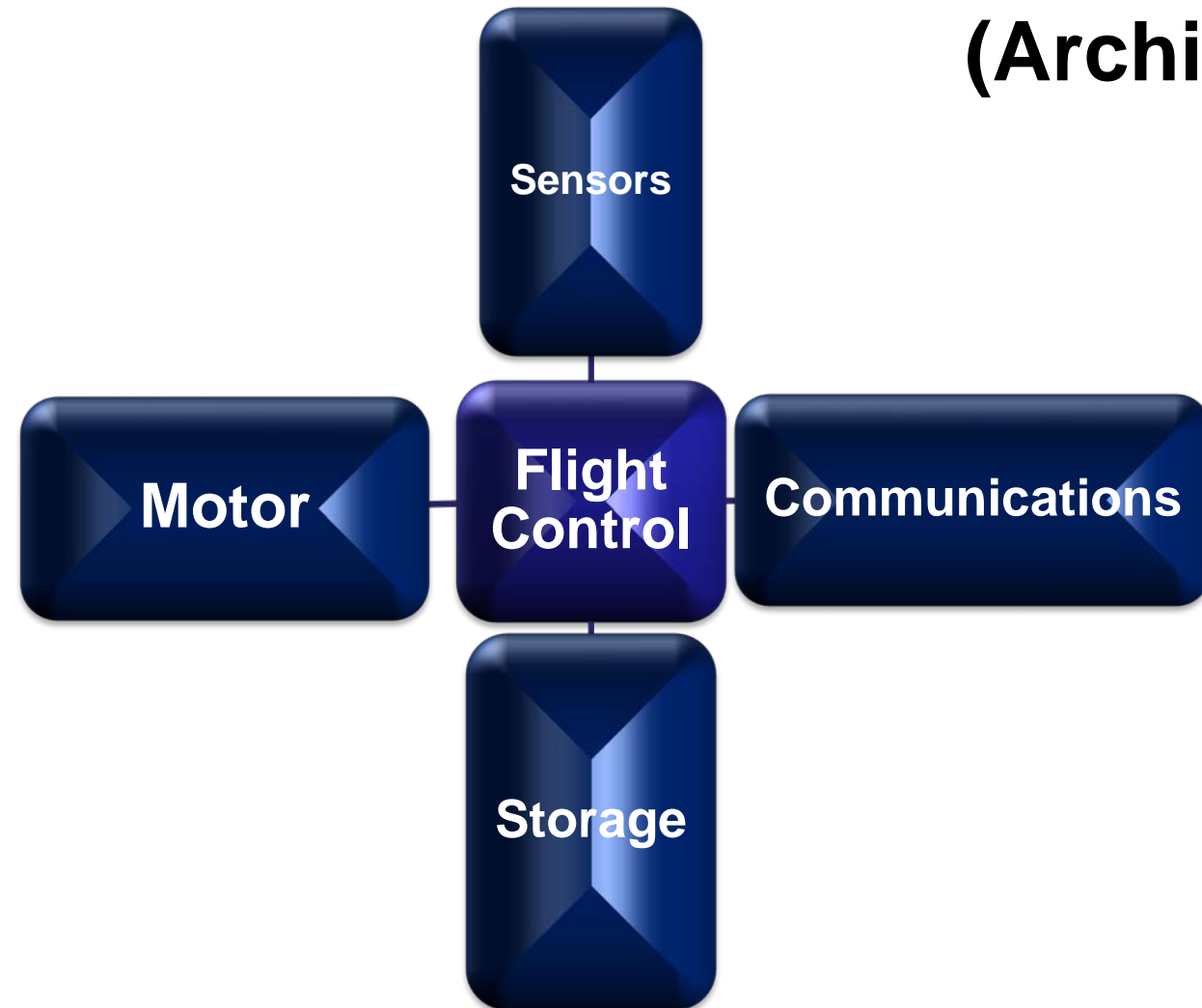
Proposed Drone

LiDAR

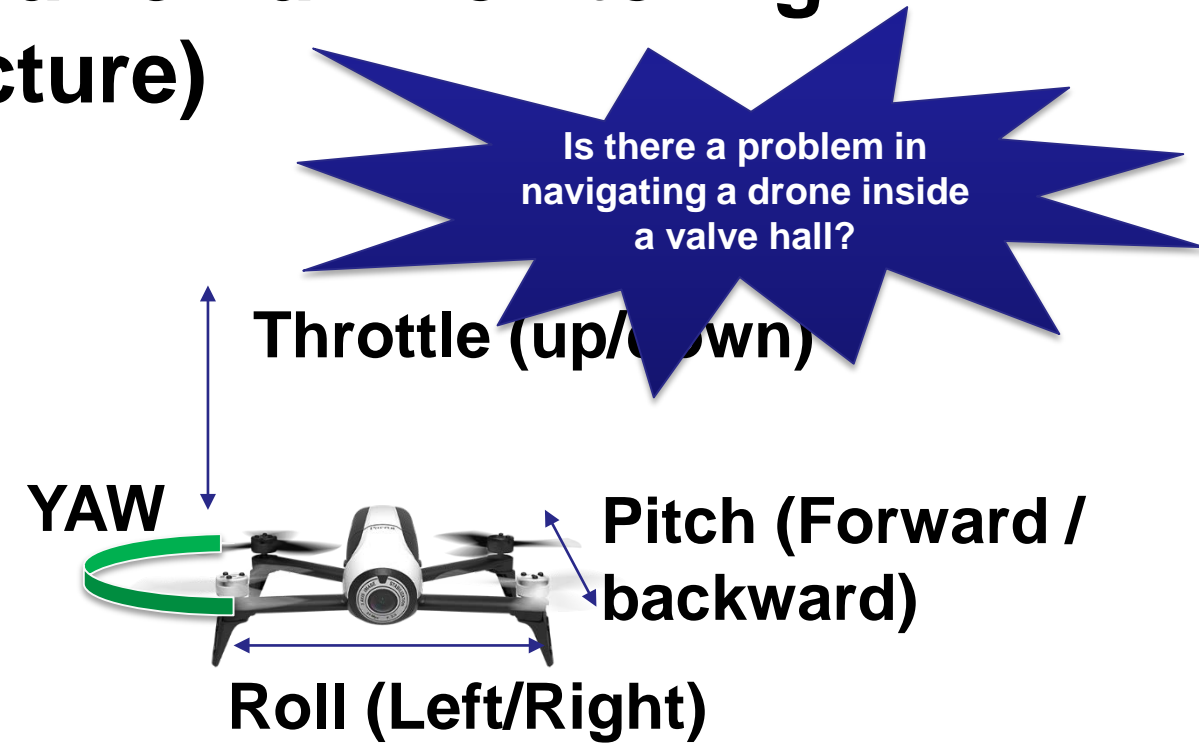


2D mapping and navigation in GPS denied environment

# An Inspection UAV for Valve Hall Monitoring (Architecture)



Drone Architecture Modules

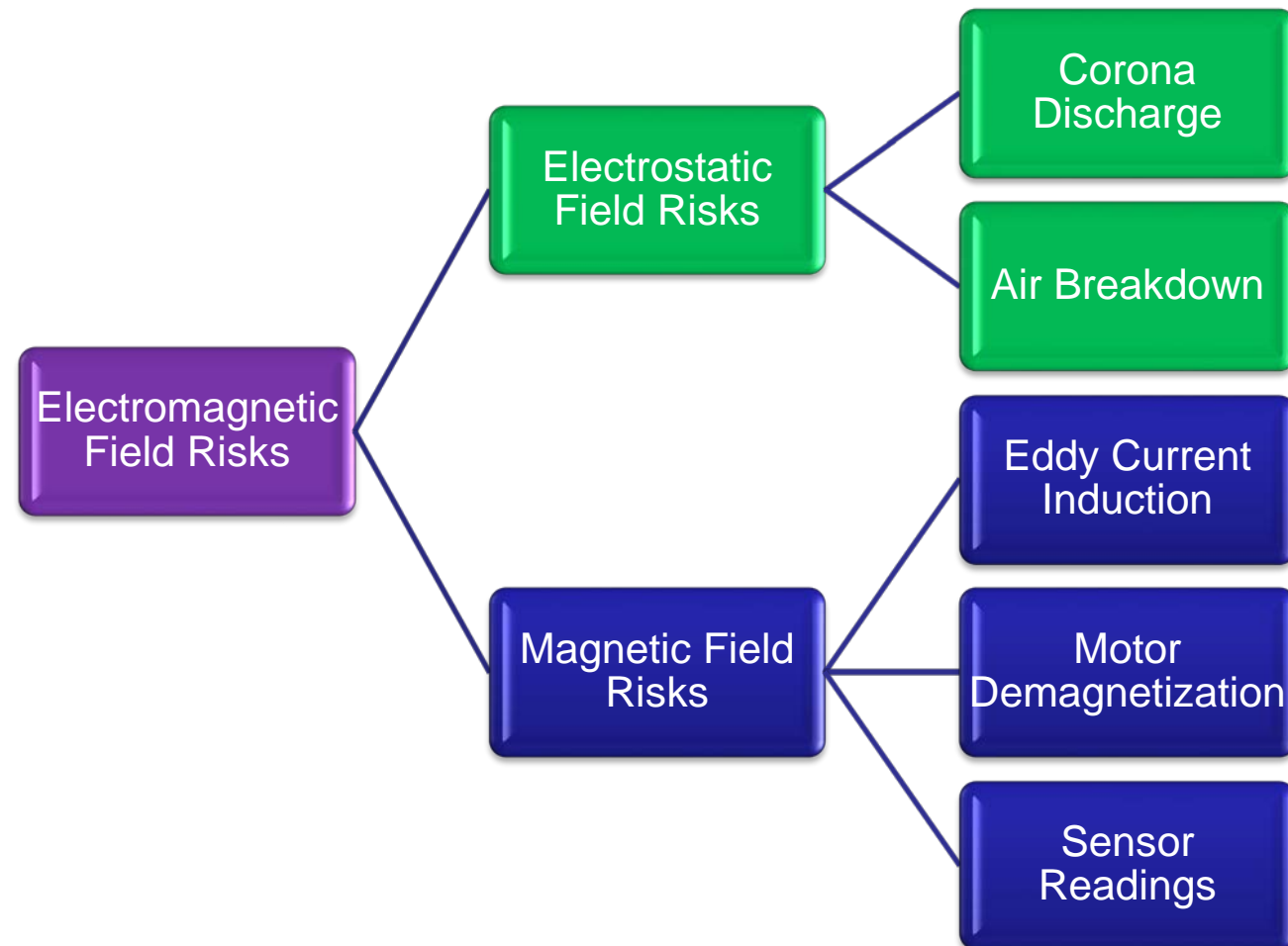


Drone Navigation Control Challenge

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

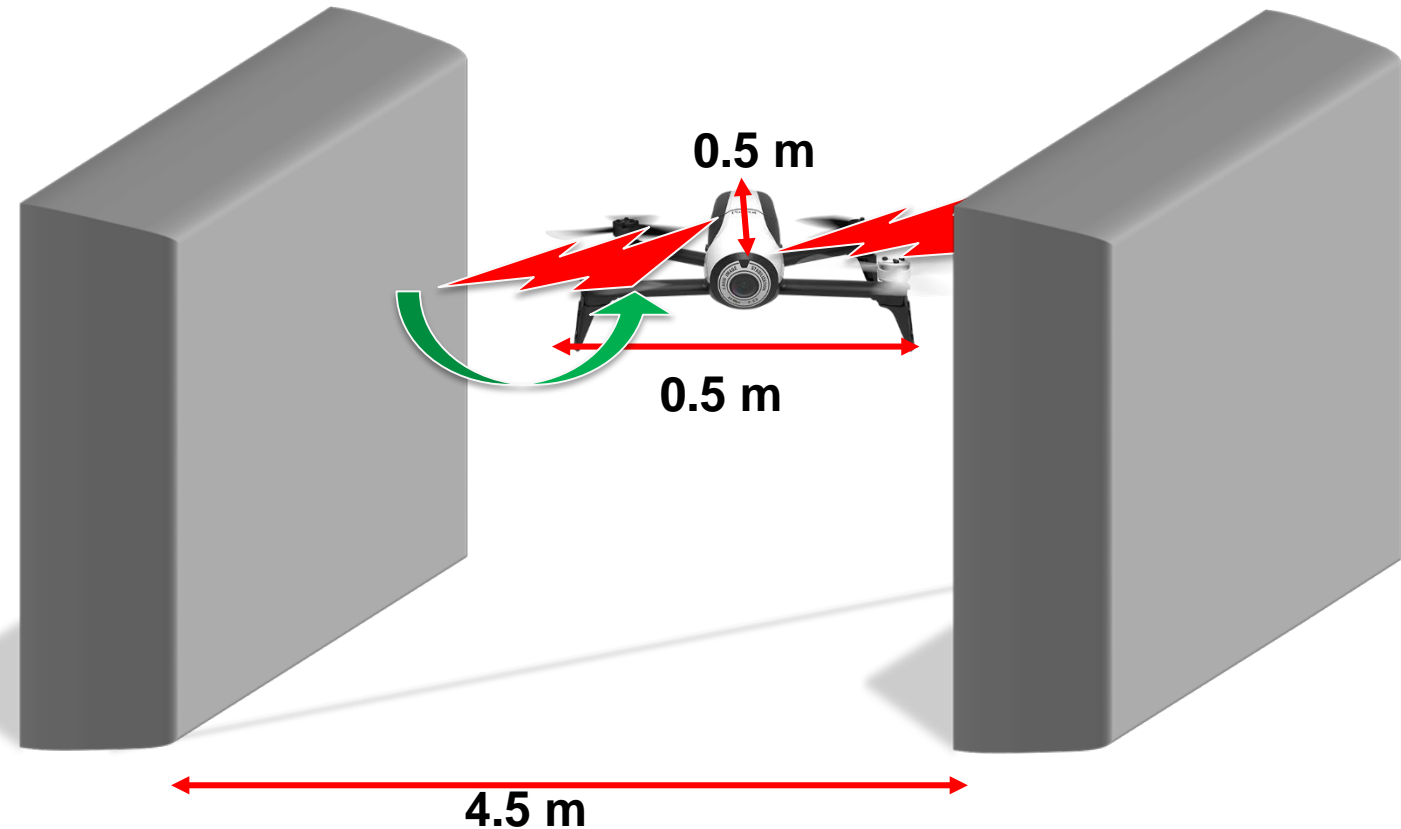
How can we guarantee normal operation of the drone in a valve hall?

# 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.
    - $\sim 2000\text{V/mm}$
  - Air Breakdown or Flashover between 2 stacks.
    - $\sim 3000\text{V/mm}$

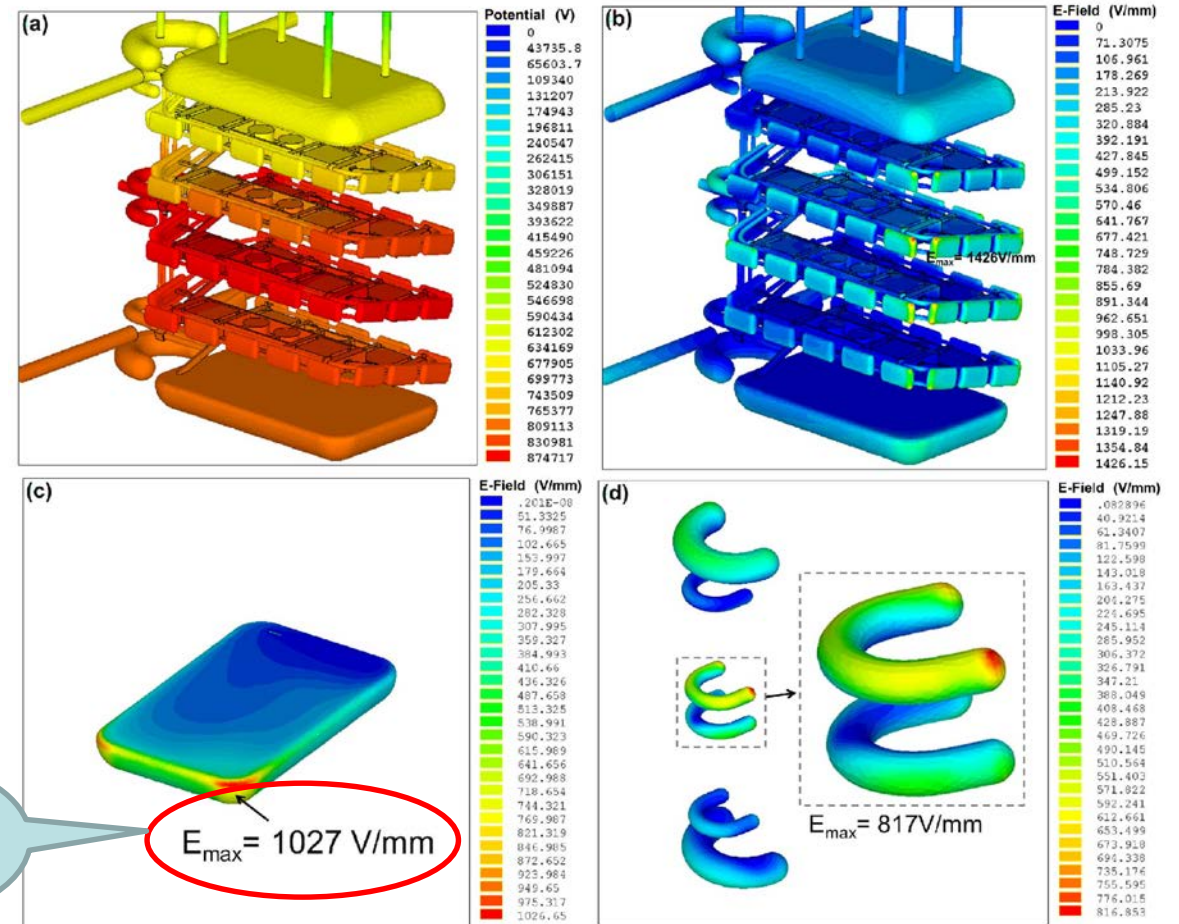
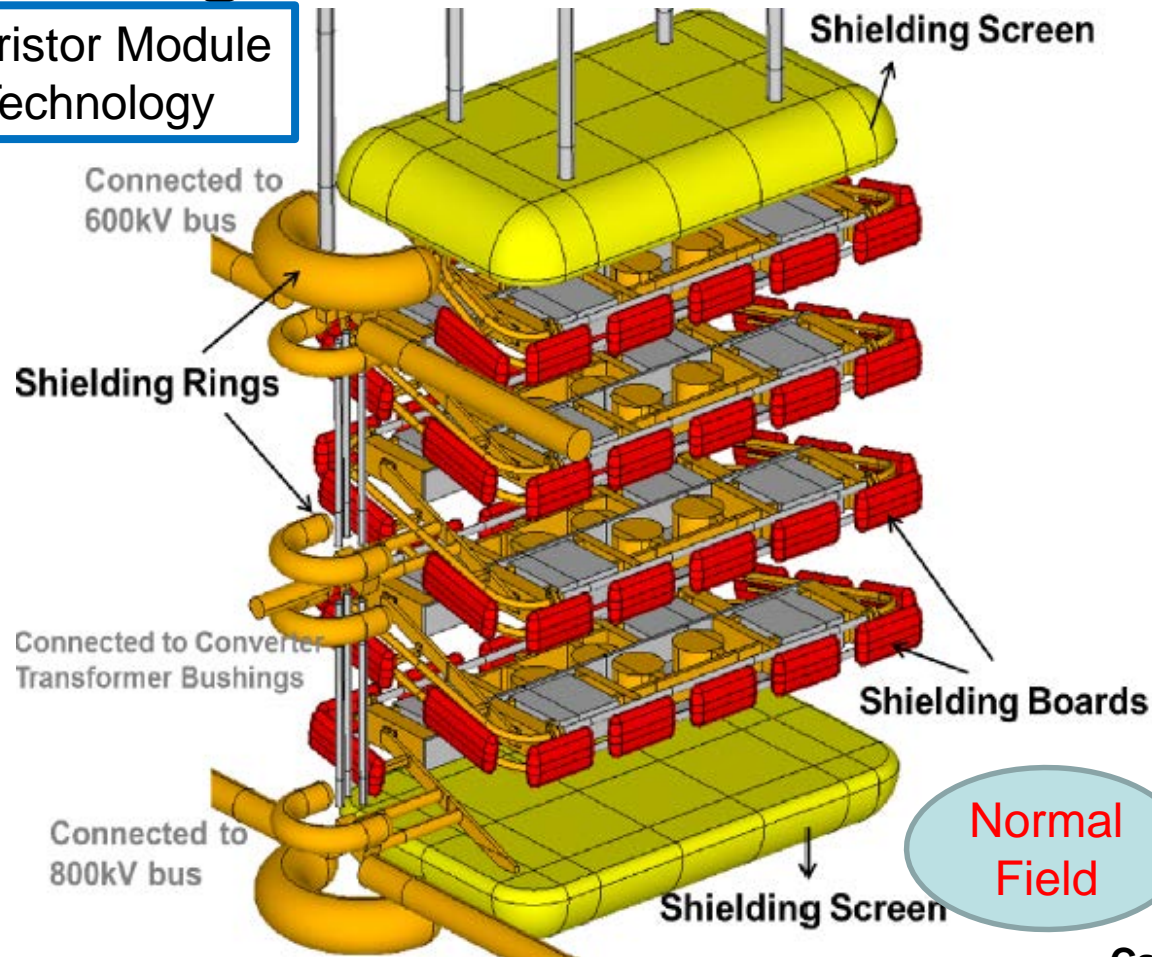


Electrostatic risks inside a valve hall



# High Electrostatic Field inside Valve Hall (Evaluation)

Thyristor Module  
Technology



Model of typical double valve used in the high voltage valve hall of  $\pm 800\text{kV}$  UHVDC converter station<sup>[7]</sup>

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<sup>[7]</sup>



## 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.

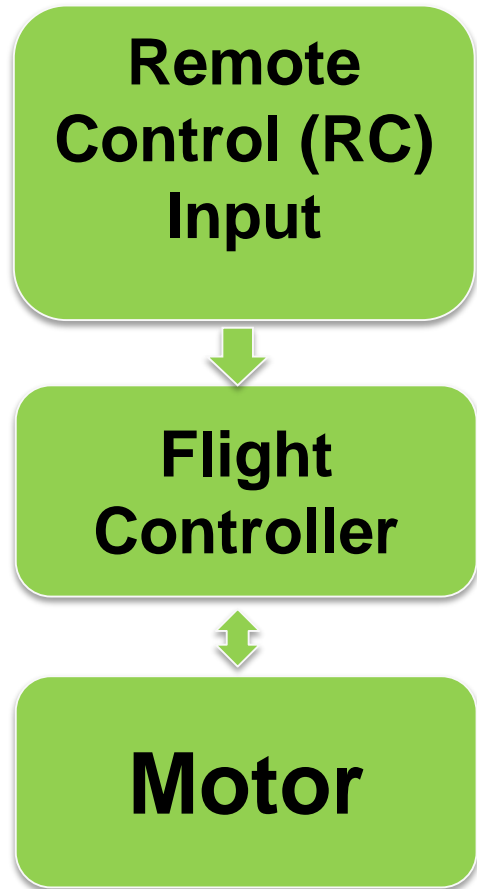
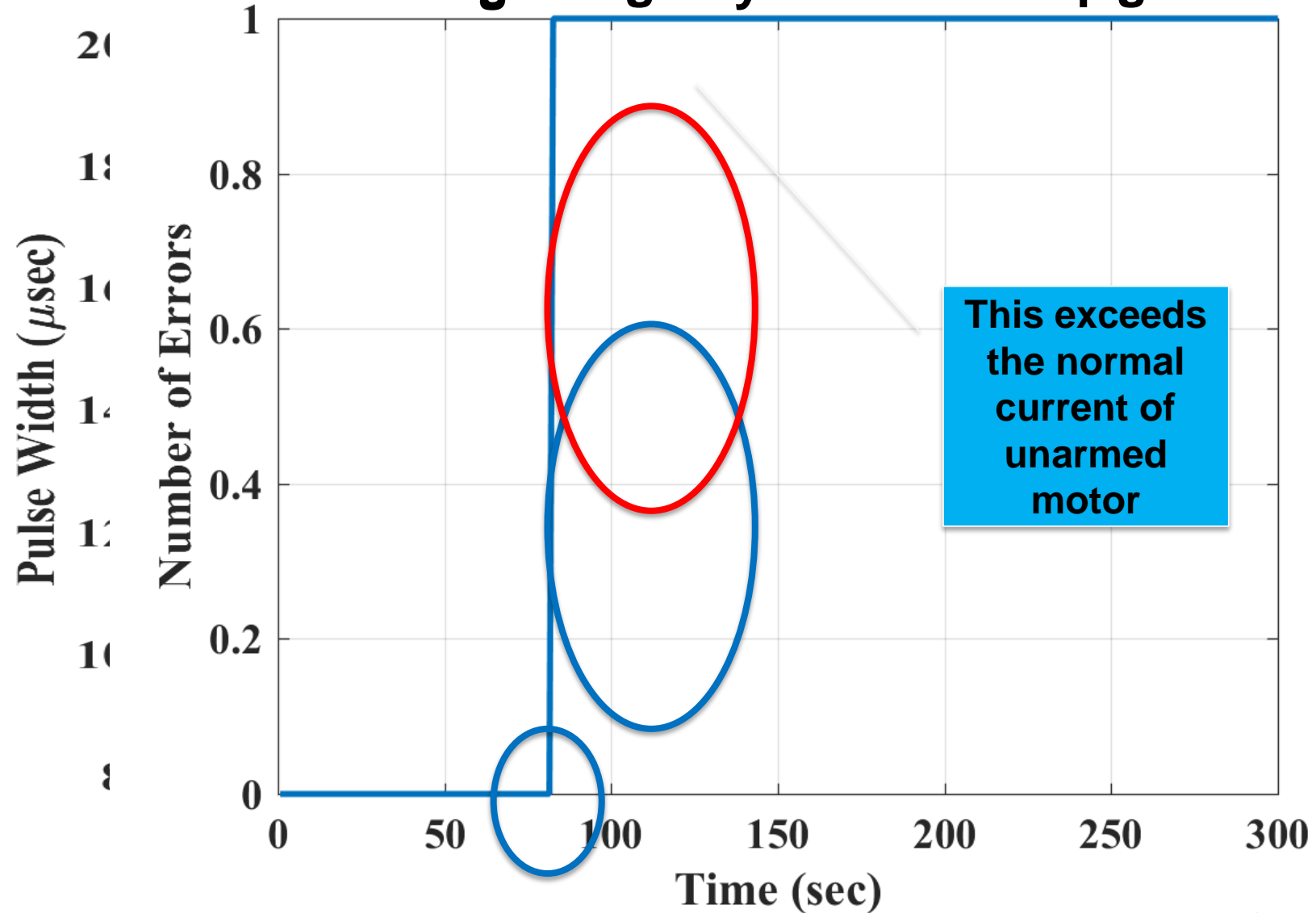
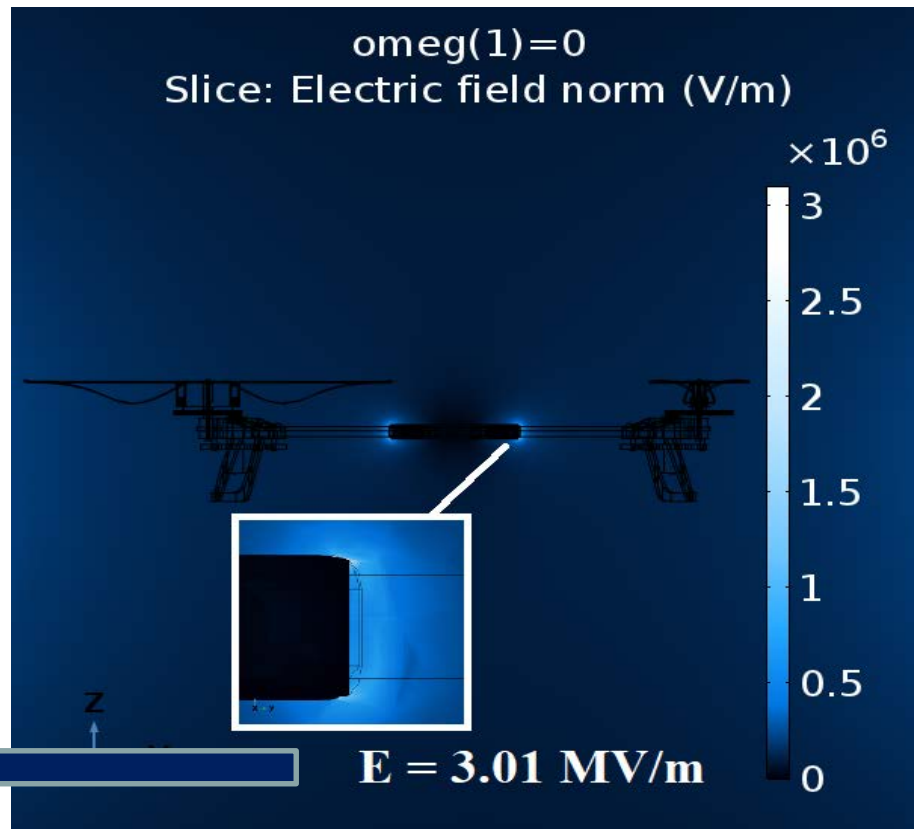


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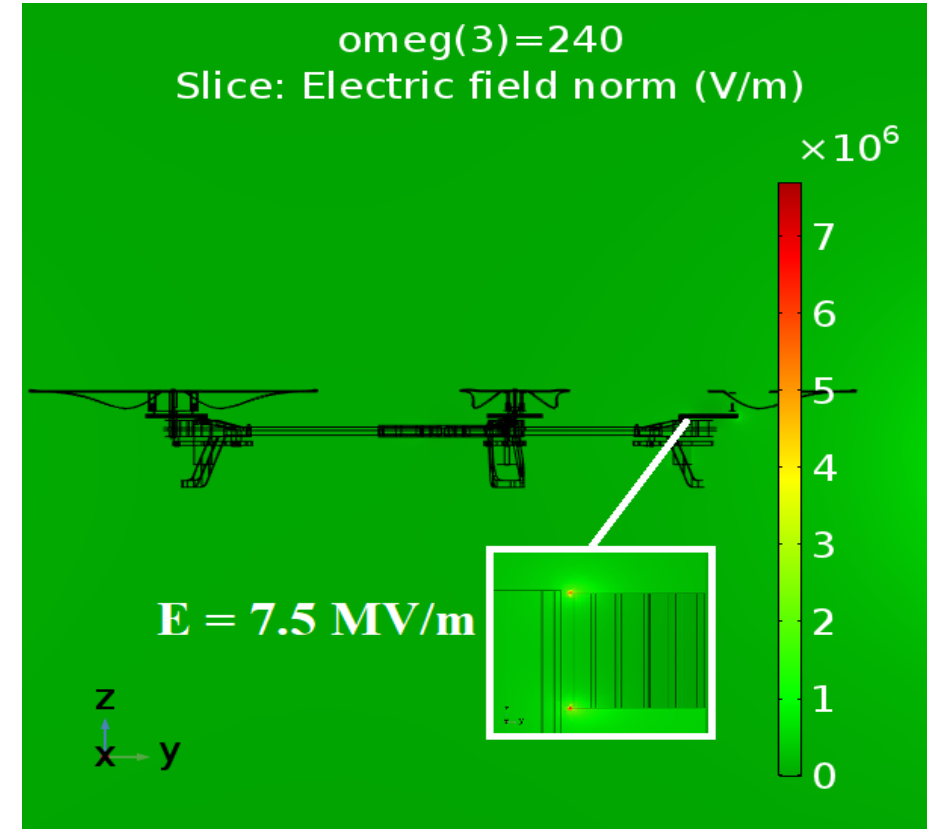




# Drone Electrostatic Field Simulations (Corona Discharge Risk)



(a)

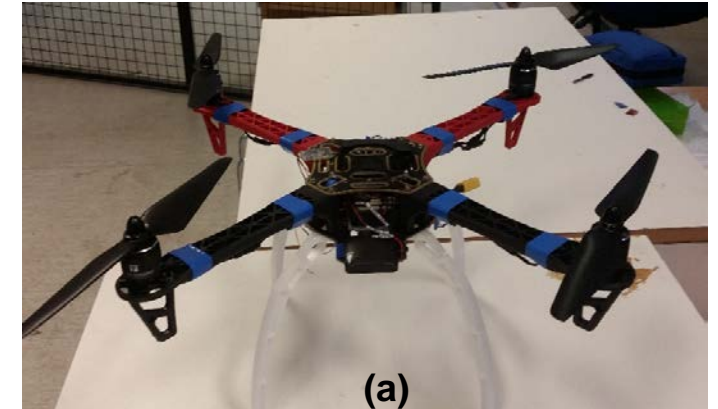


(b)

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

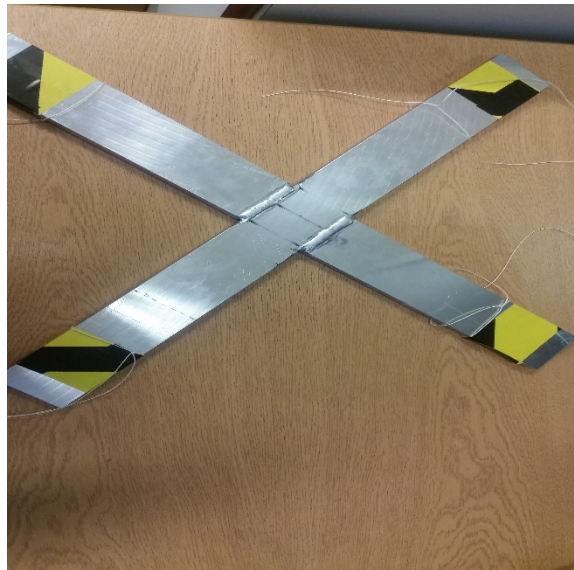
# Drone Electrostatic Field Testing (Exp. (1) Conc.)

- 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?**



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.*  $\sim 1.1$  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.

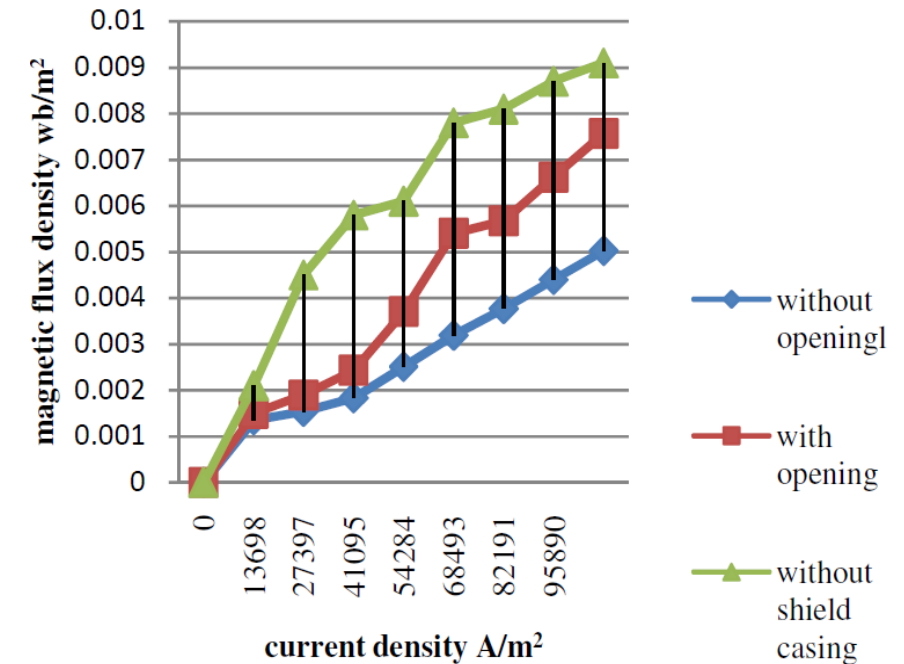


## Drone Electrostatic Field Testing (Conclusions)

- 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.

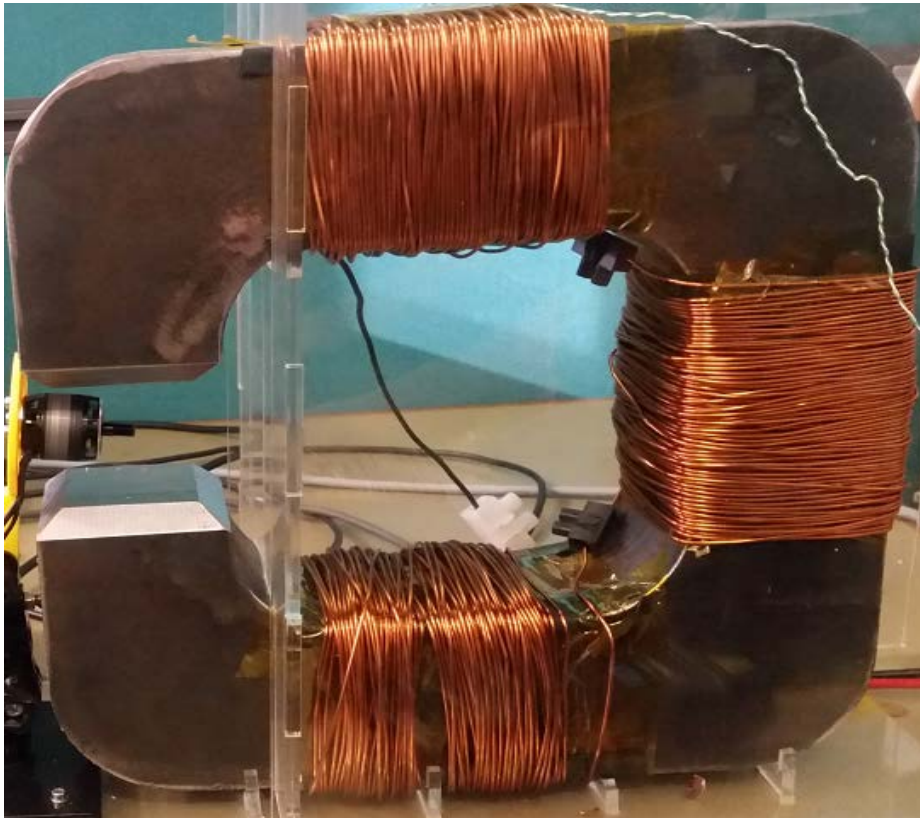
# High Magnetic Field inside Valve Hall (Evaluation)

- 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  $182.5 \text{ cm}^2$  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<sup>[9]</sup>

## Drone Magnetic Field Testing (Setup)



Magnetic Field Test rig

Motor 1



Motor 2

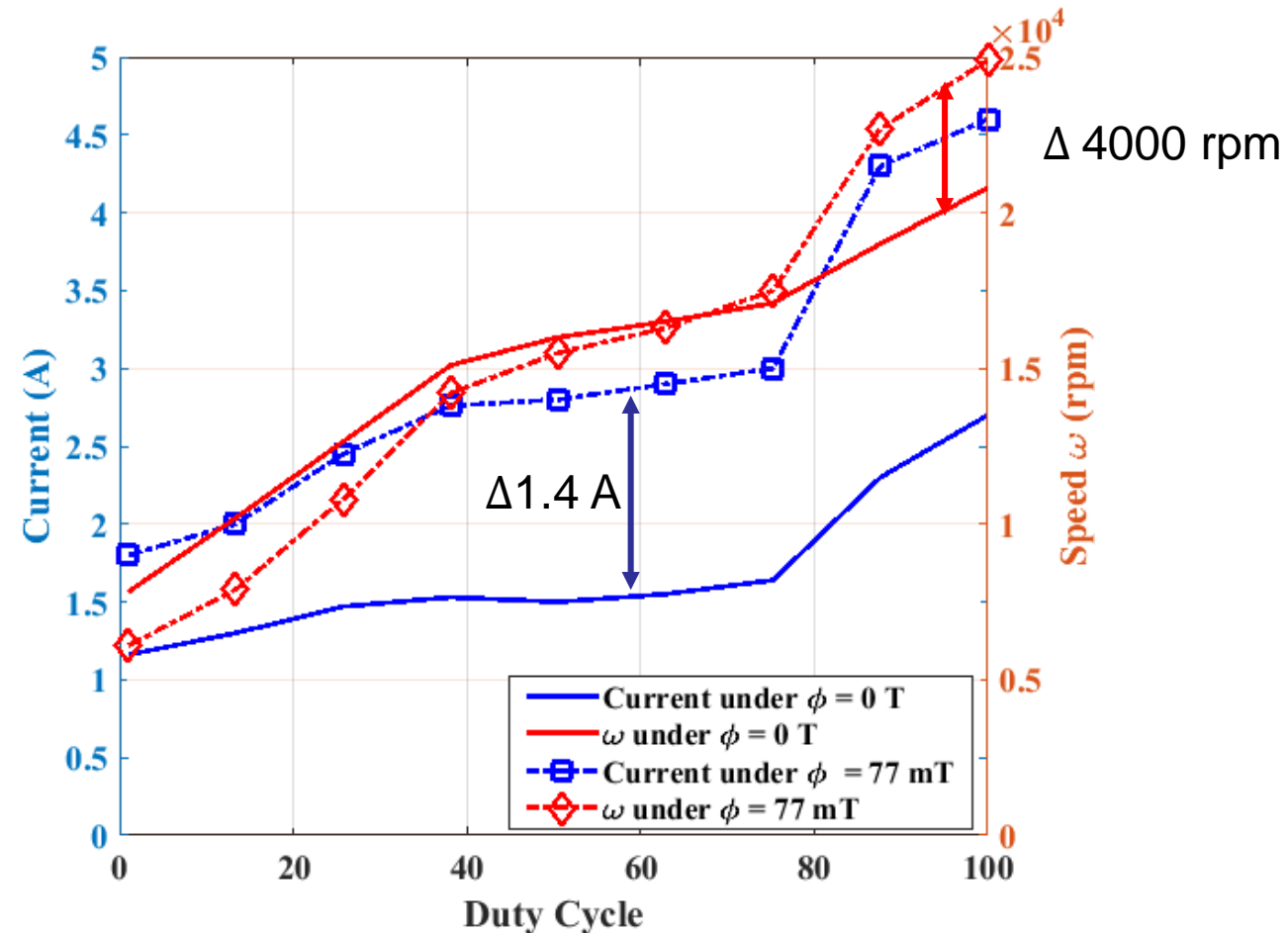


Motor 3

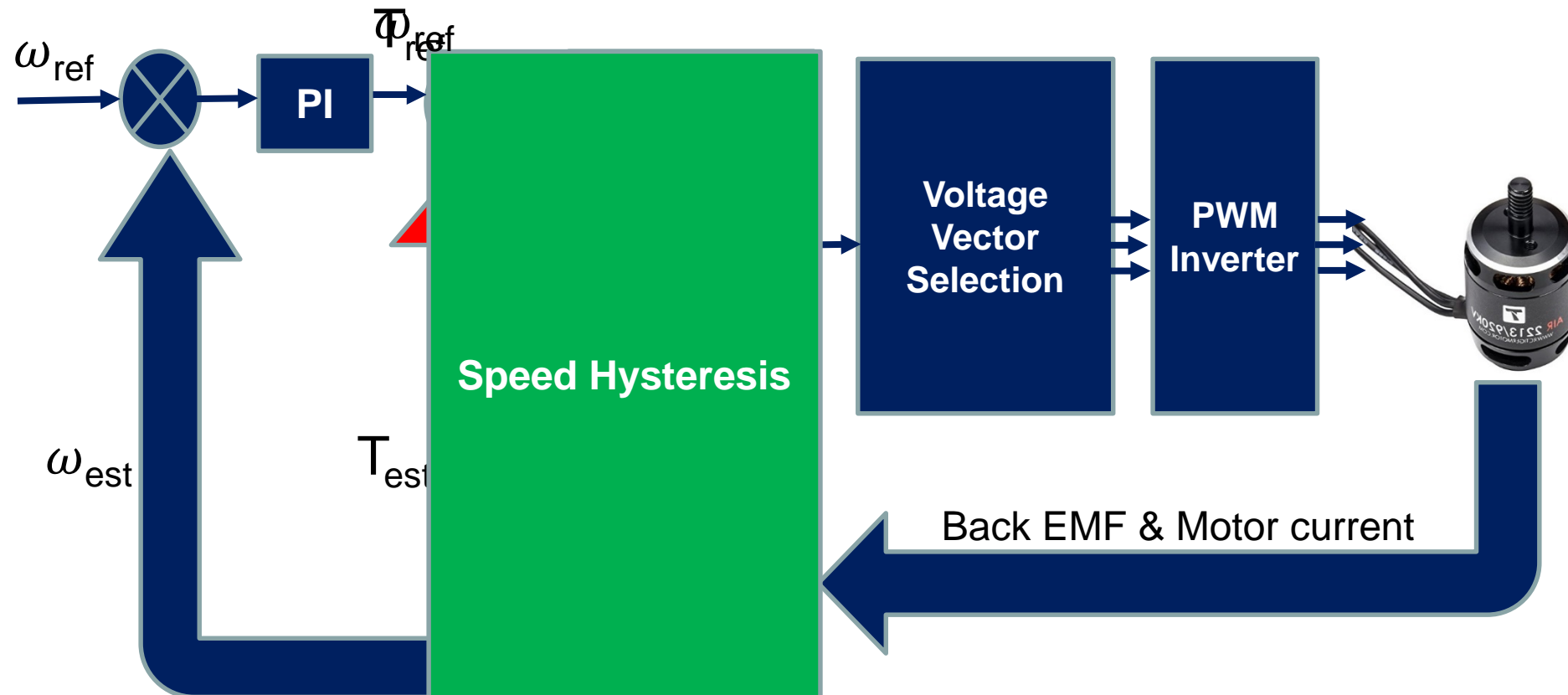




# Drone Magnetic Field Testing (Results)



# 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.



## References

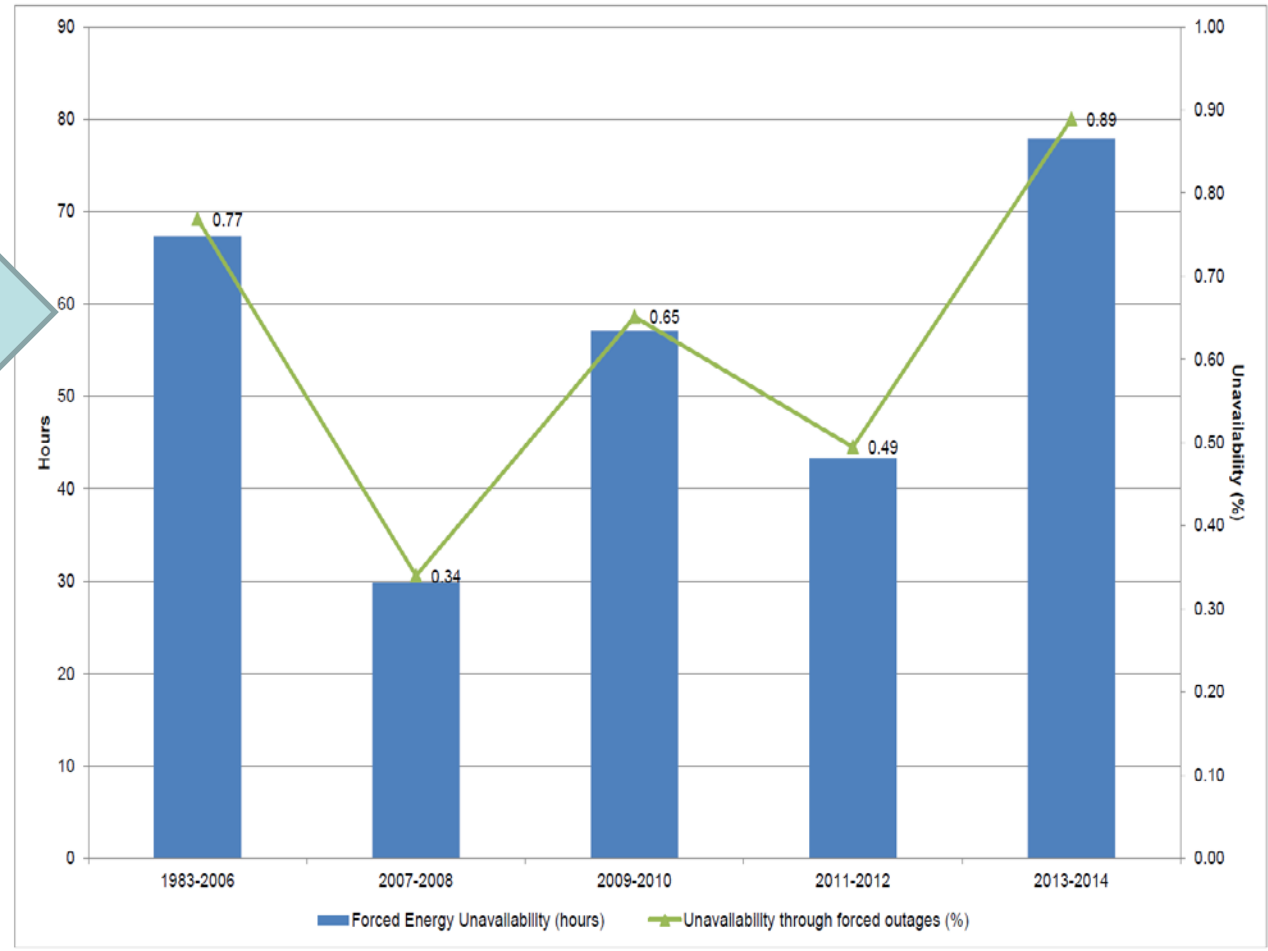
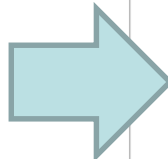
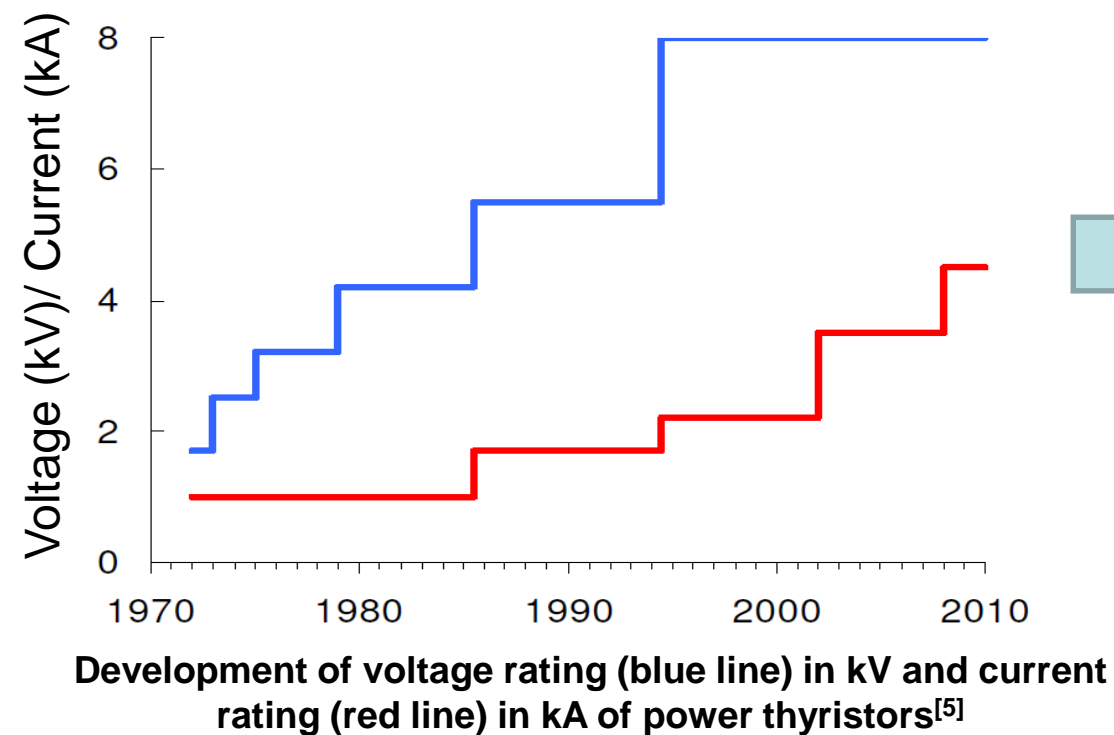
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Thank you

Questions?



# Development in Thyristor Technology



- 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.

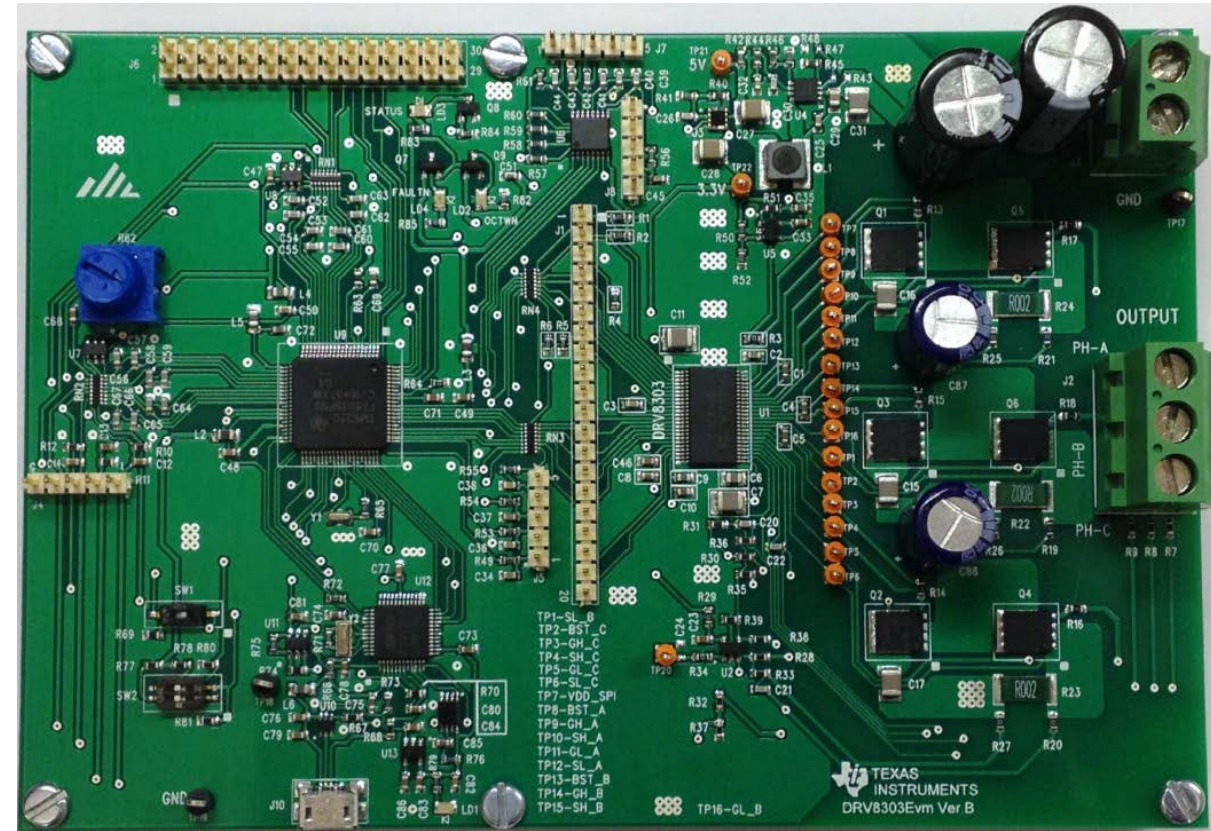


Refurbished HV lab facilities at UoM



# 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