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### **Novel Use Case of Robotic Dog Payloads for Asset Inspections at HVDC Site**

**S. ASHOK, J. MARCINKUS, C. MCCARTHY**  
**National Grid**  
**USA**

#### **SUMMARY**

The goal of this paper is to summarize the highlights of a recent asset inspection use case for unique HVDC facility part of the national grid footprint using a robotic dog and its payloads. The robot dog from Boston dynamics [1] is been used to run the inspections and evaluate the use cases. Part of the paper also deals with testing electromagnetic field strengths in various parts of the converter station to figure out impacts of clearances and asset interactions. The inspections carried out using point to zoom camera or infra-red cameras are part of use cases that normally have significant value from asset inspection and from logs of events that correlate with the events. This helps to put context for conducting routine inspections as well as a baseline to compare against the existing inspection techniques using hand-held meters and comparing the results for potential safety and reliability improvements.

#### **KEYWORDS**

HVDC, Infra-red, Robot, inspections, Assets, electromagnetic field

The Boston dynamics robotic dog use by National Grid’s HVDC Converter [2], has potential towards safety and sustainability utilizing innovative technologies. The robot is capable of manoeuvring through a multitude of terrains and inclines, including stairs, which allows it to be useful within the substation. Capable of high definition photos and videos, and loaded with a thermal camera as well, it can perform a vast amount of checks throughout the station, getting close to equipment without risk to personnel. These checks performed by the robot provide useful data for the team in determining equipment in need of servicing. Robot is also able to enter areas that are dangerous for humans, such as the energized HVDC Valve Hall.

Below figure 1 and figure 2 are images taken from a handheld IR meter to give a comparison for various points of inspections. Since the meters are involved in certain proximity, they must be well targeted images and creating baseline for routine inspection.

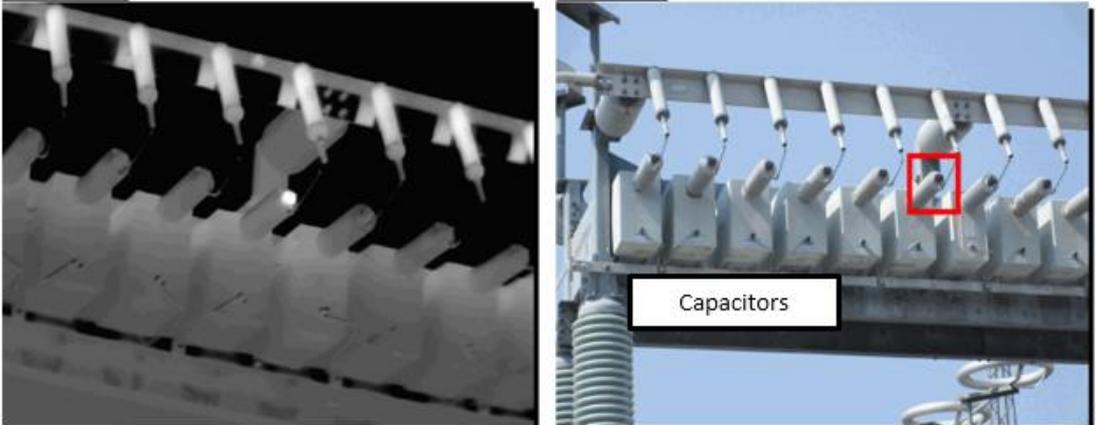


Figure 1 Thermal vs Visual Caps; near fail state vs fail state vs pass state

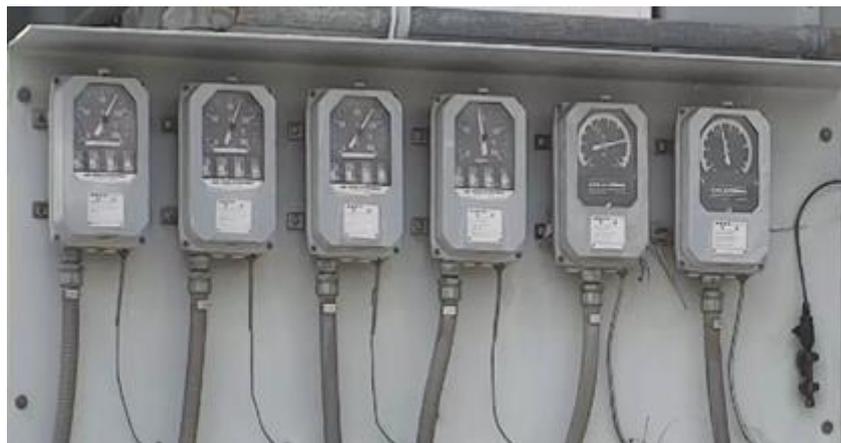


Figure 2 Another representation of filter component – fuses connections

The Robot can be operated several ways, manually with a controller or keyboard and autonomously using Auto walk missions [3]. Robot remains on an auto-dock charging station unless being used. Manual operation via the Robot tablet is like using a video game controller; it is hybrid between a video game controller and a tablet and features triggers, joysticks, buttons, as well as a large tablet screen. Auto walk missions are programmed when a user runs Robot and records the session via Robot’s app. When done, Robot will dock and save all the actions performed by the user during the recording session. This auto-walk can now be repeated in the future. Robot can have multiple different auto-walk missions saved

Converter HVDC has compiled a list of site-specific use cases for the Robot and the reasons why Robot is useful for these circumstances. To start, Robot is used to observe Current Transformer (CT) oil gauges. Checking these gauges is crucial because low oil can be/create a dangerous condition. Robot can approach the CTs and take high definition pictures of oil gauges, insulators, and other related equipment, as well as thermal reads to locate hot spots. If an emergency were to arise with one of the CTs, Robot could be used as an investigative tool, getting close to possible unsafe conditions to assess a situation or locate a root cause of the emergency.

Converter has utilized Robot to observe Filter/Capacitor/Reactor banks and other related equipment, which are typically located inside a locked fence within the yard at Converter. Robot can zoom into these banks and give high definition feedback. Since blown fuses and leaky capacitors are not always visible to the naked eye, especially from the outside of a locked fence, Robots image capabilities prove useful here. Converter uses Robot to take high definition images of Converter Transformer Oil/Winding temperature and level gauges. This is especially useful in the summer or other periods of high ambient temperature/high power level at Converter, as it avoids unnecessary exposure of personnel to the transformers but allows for us to monitor this crucial data. Using Robots Auto walk feature, we can create a mission that allows us to capture this data, and run that mission as often as deemed useful in order to provide trending and other analysis.



*Figure 3 Oil gauges for high voltage transformer equipment*

Converter also uses Robot's thermal imaging capabilities to regularly check the Converter Transformers for hot spots.

The DGA systems Converter HVDC has are located directly at the Converter Transformers. To check the status of these units, personnel are typically exposed to the high noise levels and the transformers themselves. Robot can be used to check these units without this unnecessary exposure to personnel.

Within the Valve Cooling rooms are located a plethora of gauges, sensors, switchgear, water, etc. Robot can patrol these Valve Cooling rooms, specifically on off hours when limited personnel are available, and provide useful information about the status of the equipment. Robot can provide live high definition feedback of the status the 480V switchgear, the flow sensor readouts, nitrogen levels, oil levels, and observe if there is any water present where it

should not be. There may be future use of the Robot microphone by capturing audio samples within these rooms to help diagnose pump/motor issues for Maintenance and on-call personnel.



Figure 4 Inspections conducted in Valve hall of HVDC converter

Robot can be used to investigate, as alluded to before, dangerous situations that might not be safe for personnel to get close to. This includes breaker faults and failures. Robot can be dispatched to a failed breaker and capture gas gauge data as well as breaker position/status indications.

In the Auxiliary Power room, there are many 480v breakers and feeds which pose a high risk to anyone close by if a failure or fault were to occur. Robot can be used to investigate issues within Aux Power, as well as for normal patrol in Aux Power to capture breaker status and position, inverter status, transfer switch status, etc. Since failures and faults can be unpredictable, using Robot this way prevents subjecting personnel to this room unnecessarily.



Robot is used to go places where personnel simply cannot, proven to be useful in entering the HVDC Valve Hall while the station was energized. Robot can take thermal reads from within the Valve Hall to find hot spots, and can provide live high definition video to assist in finding potential leaks or other issues



EMF testing was conducted by National Grid using NARDA test units [2] in various locations of the yard to check for any electric and magnetic field strength and to see if the robot has any effects on the assets in energized emf areas.

**Results:**

Transformer area:

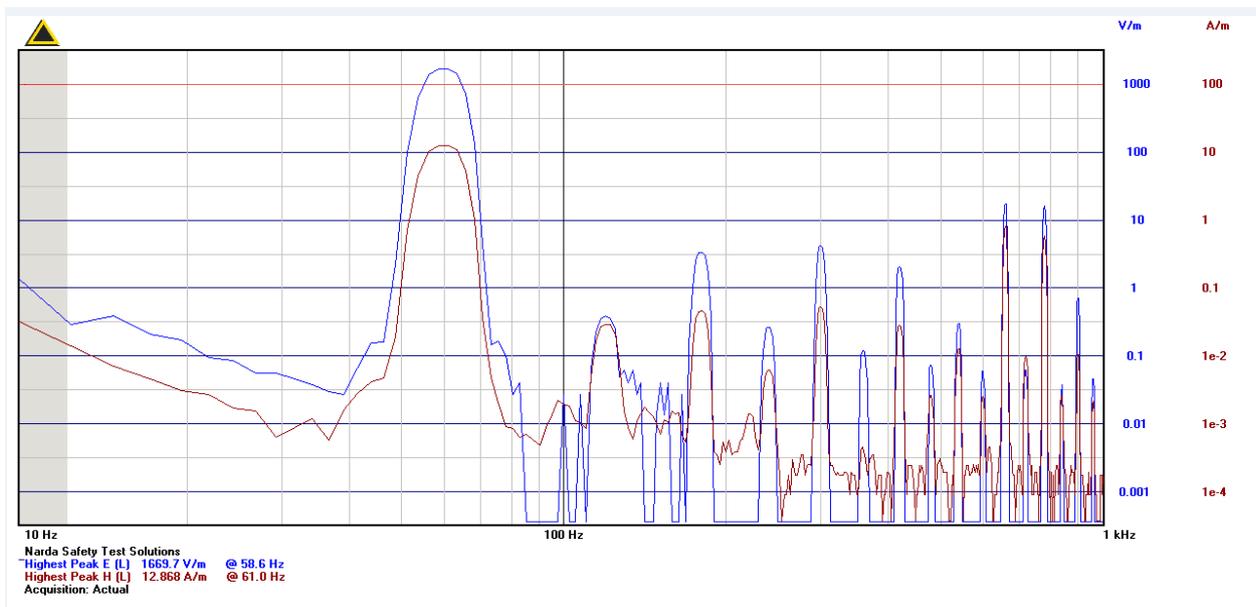


Figure 5 Transformer area emf testing - higher clearance area

**EHP50-TS Spectrum**

EHP50F Rel 5.37

Span: 1000 Hz H (Low)

WideBand E: 1632.4 V/m

WideBand H: 12.935 A/m

Highest Peak E (L) 1632.4 V/m @ 58.6 Hz

Highest Peak H (L) 12.935 A/m @ 61.0 Hz

Acquisition: Actual

### Smoothing reactor area:

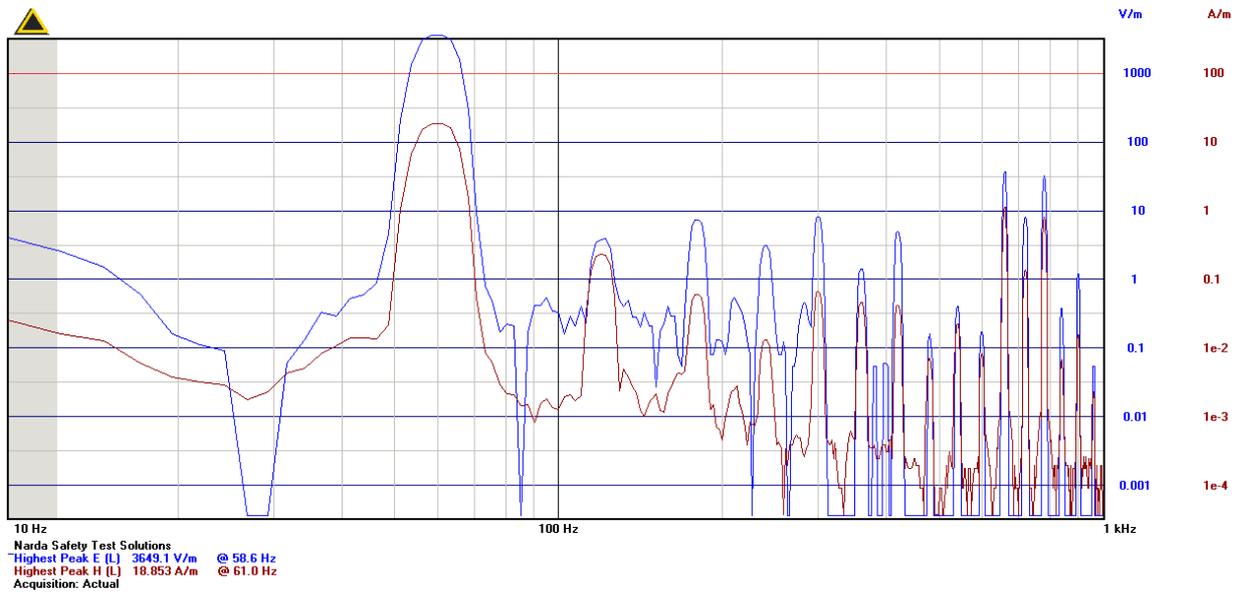


Figure 6 emf testing near smoothing reactor area with low clearances

### Reactor R21 area:

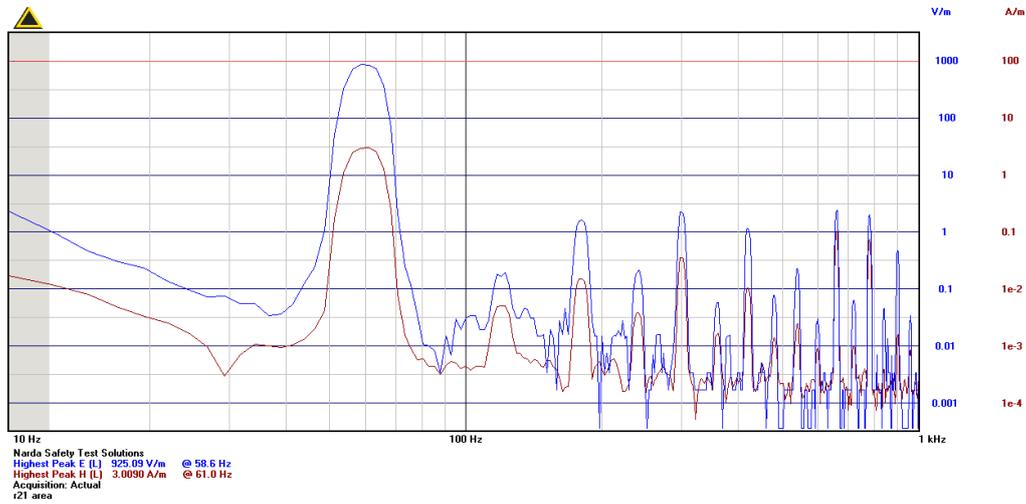


Figure 7 emf testing in reactor area 345kv energized area

Other areas of inspection with different clearance:

Location	Electric Field Strength [kV/m]	Magnetic Field Strength [A/m]
AC Filter 11 Yard	1.2	0.50
Reactor Yard	10.2	58.3
Thyristor Valve Hall	3.8	8.7

Due to the test unit accuracy issues and clearance levels, the results may not be fully reflective of the data, overall the data suggests the emf measured due to the clearance levels of the equipment and outdoor equipment, suggested highest emf near the transformer area with the outgoing bus compared to the valve hall and filter areas. More tests need to be done in order to verify the accuracy of the emf results along with having the robot run into various dead zone areas with communication issues to give a better issue of emf.

## **Conclusions:**

For EMF measurements, NARDA test units measured levels on site at Converter, as well as to test the effects of the robot on the equipment. Robot was found to operate safely around running equipment, including inside the Valve Hall, although the testing needs more data sets and more runs to verify the accuracy of the results. Measured EMF levels suggested highest EMF near the transformer area with the outgoing bus compared to the valve hall and filter areas and results could be varied based on the clearance areas

Robot can be used for general patrol of the exterior yard at Converter. Using the Autowalk feature is particularly useful here, as missions can be programmed to walk the yard and capture images/thermal reads, and these missions can be repeated as a daily activity. Operators can also use Robot to investigate potential security issues, such as unidentified individuals. It can be used to investigate potential threats to operation reliability as well, such as unknown debris in the area, animals, etc.

These are some of the ways Converter HVDC is using and plans to use Robot. As more payloads are released and tested, and more training is provided, the Robot will find many more uses within the station.

## **BIBLIOGRAPHY**

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[3] <https://www.bostondynamics.com/spot/resources/national-grid>

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