Prototype probe development for Liquid Injection Shutdown System Tube Gap Detection by Remote Field Pulsed Eddy current technique

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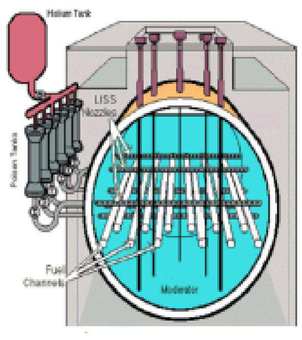
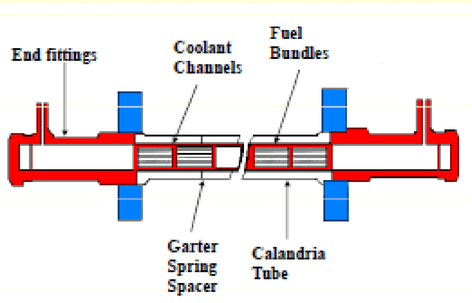
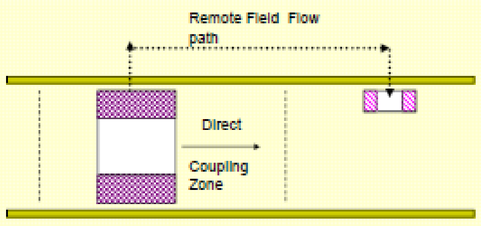
Objective



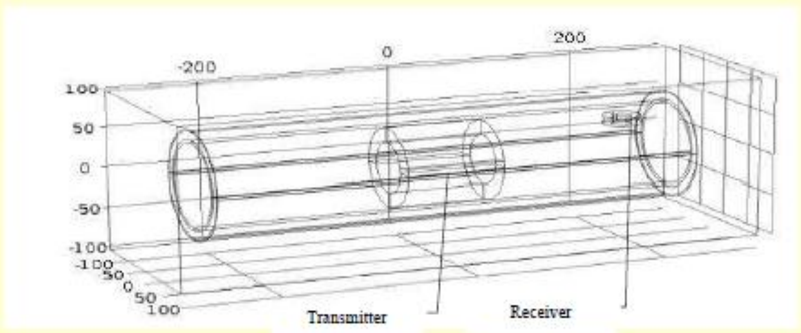


Pressurised Heavy Water Reactors play a prominent role in contributing power for the Nuclear Energy Programme in India. In 540 MWe PHWR reactors, there are horizontally placed Liquid Injection Shutdown System (LISS) tubes for injecting poison into the moderator to clamp down the nuclear power under trip conditions. The Horizontally placed LISS pipes are placed perpendicular to the horizontal Coolant Channels in the inter lattice positions. The gap between the coolant channel and the LISS tube is critical considering the possibility of fretting damage in the event of closing of the gap. The Coolant channel consists of two co-axial tubes called Pressure tube (inner) and Calandria Tube (outer). The gap between LISS tube and calandria tube cannot be measured directly as the whole core of the reactor is enclosed in a vessel called Calandria vessel. Only easy access to the core is through the bore of the pressure tube for employing any inspection technique for measuring the gap and the probing medium has to penetrate the pressure tube and calandria tube barriers. Electromagnetic technique only appears to be feasible for the inspection.

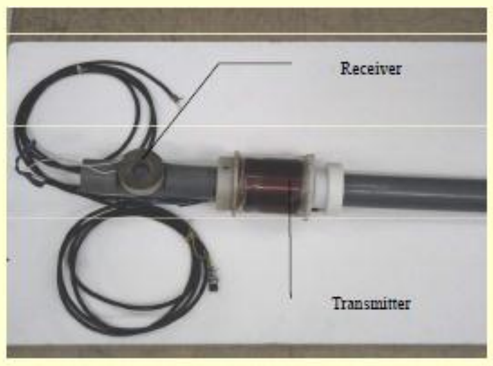
Philosophy of Detection



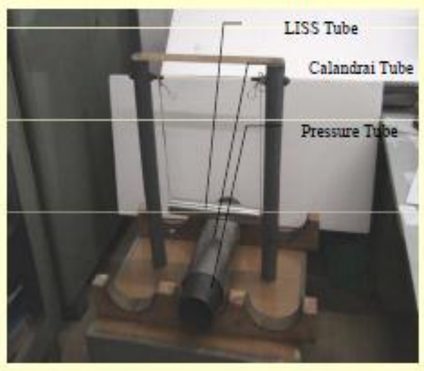
The Remote field detection is based on the fact when a coil placed inside a tube is excited, it generates direct field and remote field. Direct Field which emanates within near vicinity in the tube. Remote field emanates from the coil penetrates the metallic barriers and traverses in axial direction and makes a re-entry into the tubes. The sensor consists of transmitter coil and receiver coil placed 1 Diameter to 2 Diameter distance part. The transmitter coil which is located in the coolant channel is excited with Pulsed current source. The receiver coil is used to pick up the remote field which links with LISS tube.



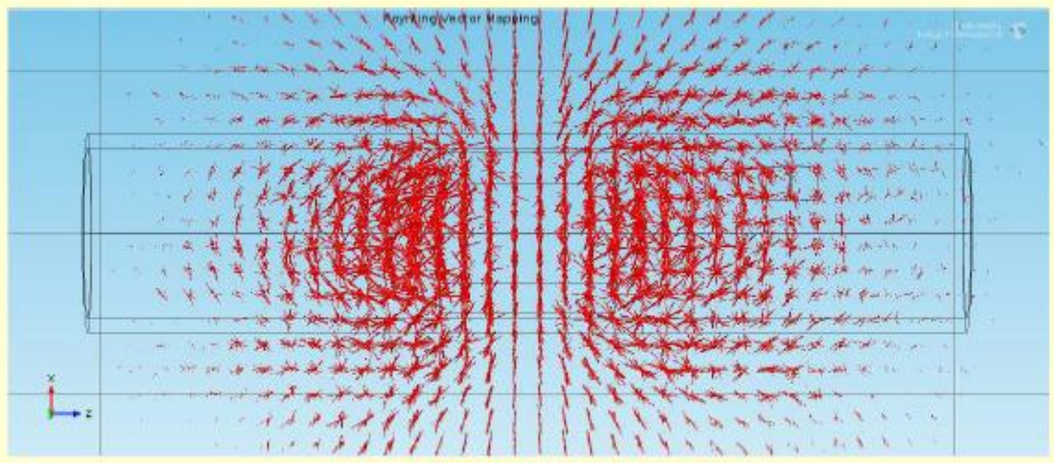
Schematic of Sensor



Proto type Sensor



Experimental setup



Poynting Vector Mapping

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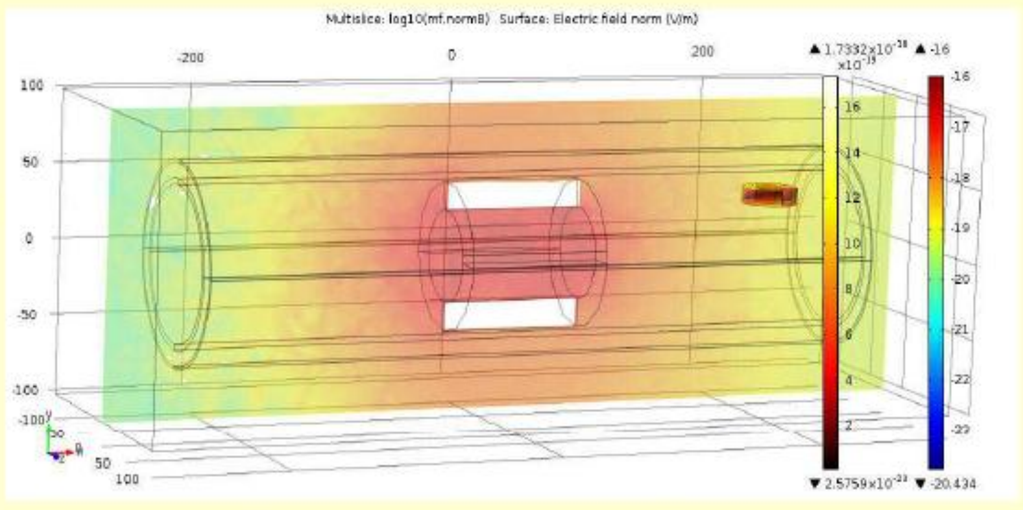
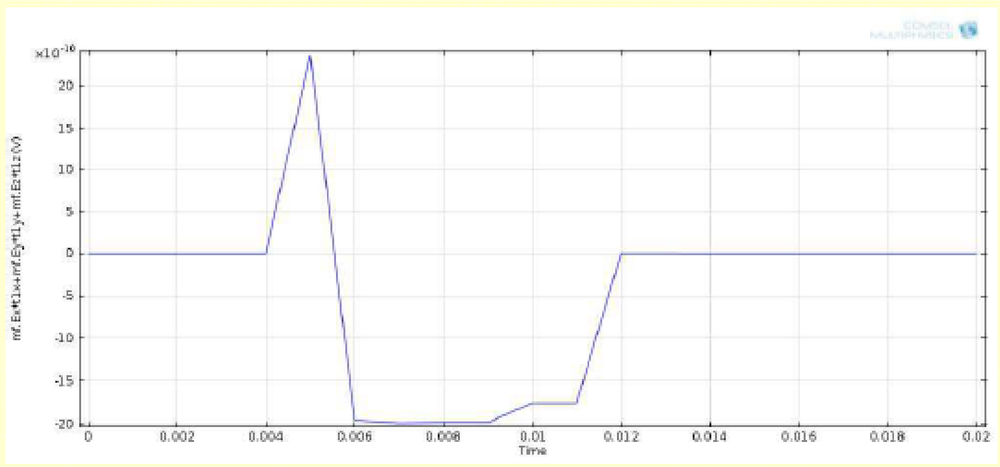
The Poynting Vector gives an inference on the Electromagnetic Energy flow in the vicinity of the sensor. The remote field emerges from the transmitter and penetrates the metallic tubes of coolant channel and traverses in axial direction (outside the coolant channel) and makes a re-entry into the metallic tubes at distance of 1D to 2D from the transmitter. The re-entry point can be inferred from the Poynting Vector Field at location where the Poynting vector makes a reversal of the direction.

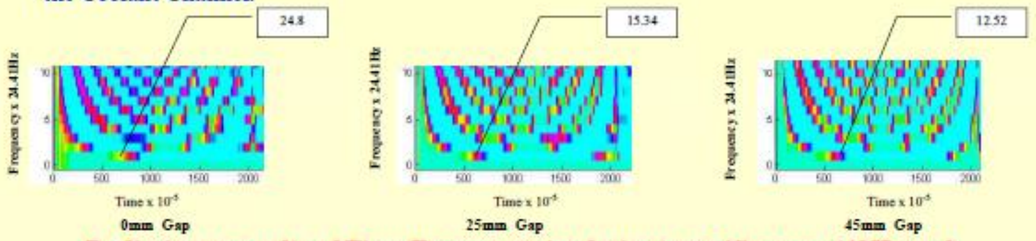


Plot of Flux Distrubution of the transmitter coil and Electric Field distribution in the pick up coil



Simulation of Voltage induced in one turn of the Pickup Coil

The pick up signals are signal conditioned and acquired in High speed Data acquisition system. Time-Frequency analysis is carried out and Time Frequency zones are identified which are sensitive to the variation of gap between the LISS tube and the Calandria tube of the Coolant Channel.



Preliminary results of Time Frequency Analysis at specific zone (49Hz and 0.00635s) for varying gap between LISS tube and Coolant Channel

The preliminary results are obtained by varying gap between LISS tube and Coolant channel. The Time-Frequency analysis is carried out and amplitude values are sampled at specific Time Frequency zone (49 Hz and 0.00635s). Trails are being carried out to establish the consistency.

The LISS tube gap detection prototype sensor based on Remote Field Pulsed Eddy Current Technique appears to be promising method. The Pulsed Eddy Current technique is a broad band technique and when applied in remote field mode has capability to detect LISS tube through the metallic tube barriers of the coolant channel. The distance between the Transmitter coil and Receiver coil can be optimized by mapping the Poynting vector and identifying the zone where reversal of vector direction takes place. The Coil pickup voltage was simulated for one turn of coil. Preliminary Time frequency analysis of the signals show some specific zone sensitive to gap variation between LISS tube and the Coolant channel. Exhaustive trails are being carried out to establish the technique.

References

[1] Binfeng Yang, Xuechao Li, 'Pulsed remote field technique used for nondestructive inspection of ferromagnetic tube' NDT&E International, 2009.