Project Design Review

Delivery Reliability for Natural Gas -- Inspection Technologies

Prepared for:
DOE-NETL

By
Gas Technology Institute
1700 S. Mount Prospect Road
Des Plaines, Illinois 60018

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Program Overview

As part of the Delivery Reliability for Natural Gas - Inspection Technologies Program, Gas Technology Institute, GTI, is expected to develop the Remote Field Eddy Current (RFEC) Technique to a suitable inspection technology for use in unpiggable pipelines. During Phase I, GTI investigated optimal exciter and sensor coil designs and preferred arrangements, in general, and in particular, designs and arrangements suitable for integrating the technology with a robotic platform. In this phase, GTI collaborated with robotic developers at Carnegie Melon University (CMU) and other inspection technologies developers through meetings, emails, and teleconferences.. The collaborating groups made an excellent start at laying out the framework for producing a robotic platform with inspection capabilities. As part of this process, groups had to come to a consensus for communications between the robot and the inspection technologies. Another important GTI task was the physical design of the two modules that will house the sensor equipment, and the electronic design that will drive the RFEC sensors, collect the data, and communicate with the robot and the robot operator(s).

Design Process, Problems, and Solutions

In order to create a solution for the sensor's integration to the chosen platform, Explorer II (X-II), GTI first had to define the problem. The first constraint was GTI sensors must be able to inspect 6" and 8" natural gas pipelines. RFEC requires the sensing coils to be close to the pipe wall. X-II requires them to be able to collapse into a volume of 4" diameter and 5" in length for navigating restrictions. Other issues imposed by X-II include limiting the number of modules for RFEC to two and limiting the weight of these modules. Both of these constraints relate to the overall weight of the robot, which has direct implications on the battery life of X-II.

In order to develop a solution, GTI had to consider the necessary components volumetrically. RFEC inspection requires a drive coil, multiple pickup coils, and supporting electronics.

Drive Coil Module

The easy task was designing the exciter coil module. This module will house the drive coil's associated electronics, i.e. amplifiers, and the drive coil will essentially be wrapped around this module as shown in Figure 1 (protective cover not shown).

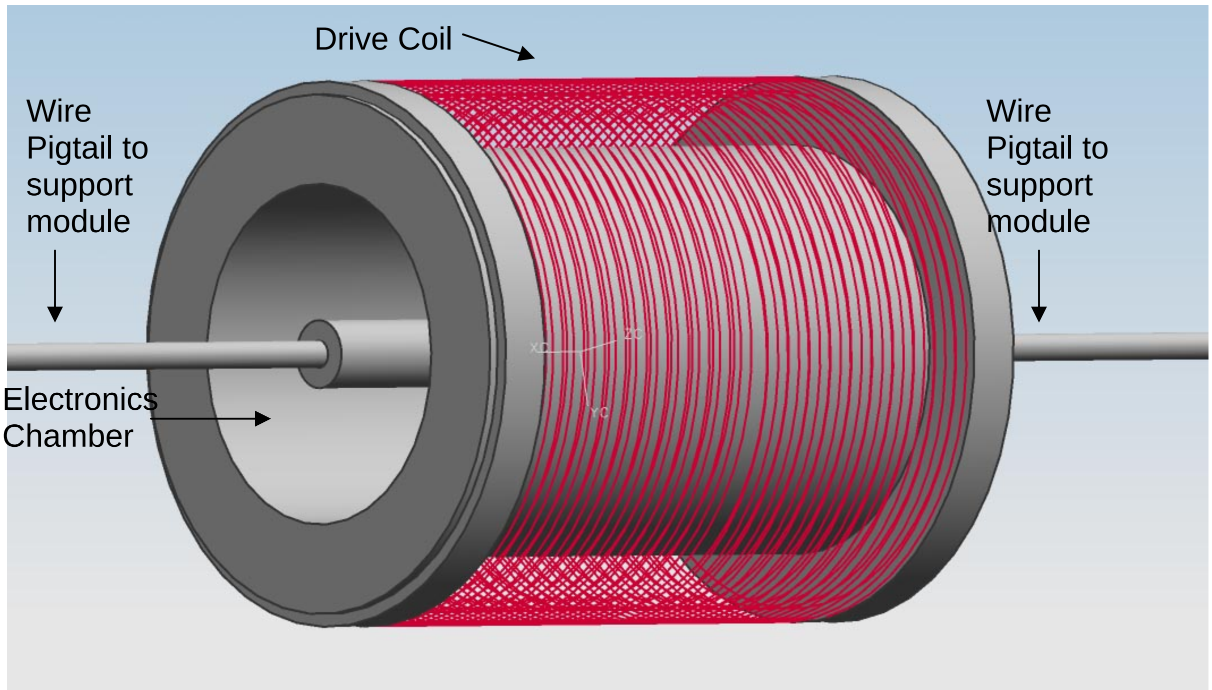

Figure 1: Planned design for the drive coil module.

Pick-up Coil Module

Based on the size of the pickup coils GTI currently uses, ample wall coverage could be attained with 20 coils. The mechanism for extending and collapsing these coils must maintain the correct orientation of the coils with respect to the pipe wall. The sensing module will support the pickup coil array and its associated electronics.

GTI is currently working on three designs for this module. Two of them are proprietary and therefore, will not be discussed in great detail in this report. At this time, GTI has not chosen the design that will be prototyped. Further design work is necessary to determine which design is best suited for inspection. GTI intends to make this selection by the end of August 2005.

The first design is called the Johnny-Ten. It was presented at the Project Design Review and is shown in Figure 2. It is a very durable design and should be able to withstand the pipeline environment. It is more developed than the other two designs as it was designed using existing parts for motion. The mechanism is a crank slider. The “mop-head” will be spring-loaded to rotate open to align with the pipe wall and close during retraction. It will also have a mechanism that will allow it to conform to and ride the pipe wall. One of the more difficult aspects of this design is its bulkiness. The weight on this design may be more than the robot can handle. Also, there may not be enough room for the electronics.

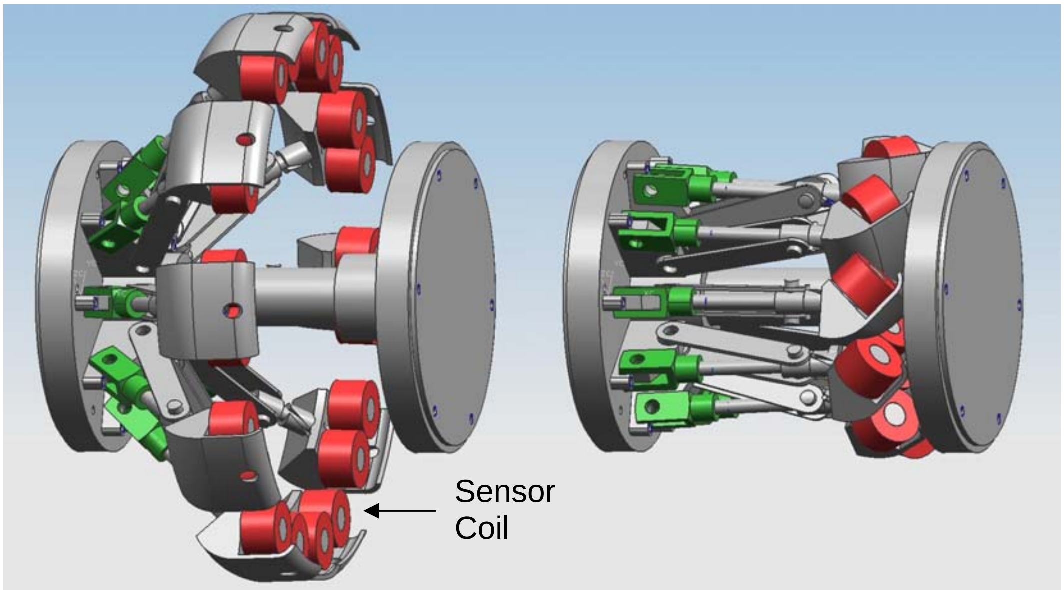

Figure 2: 3D model of Johnny-Ten, shown extended and retracted.

The second design was also presented at the Design Review. For proprietary reasons, pictures of this design will not be included. Features of Expand'O'Coil that make it a desirable choice for the prototype mechanism include, being able to maintain proper orientation of the pick-up coils to the wall at any degree of extension, (up to 12" in diameter), and it will only require 3.5" of the 5" length limit. The additional 1.5" that will be freed up by this design will allow enough room for the electronics required to acquire data. This design will allow for measurement through areas with ovality or welds but will require minor modifications to withstand the dirty environment of a distribution main.

The third design GTI is considering is the Outback. This design is also able to maintain proper orientation of the coils to the pipe wall through various degrees of extension and requires 3" or less of the length of the module. This benefit should provide enough space for electronics that the electronic components could be "stock" parts rather than repackaged for GTI's needs. The Outback design also extends to 12". It would be easier to manufacture than Expand'O'Coil but may not have enough "give" to ride over all irregularities in the pipe wall. This design would also require a bit of work to prepare it for the pipeline environment.

Electronics

Additional design work included developing an electronics diagram. This diagram is shown in Figure 3. The Lock-in clock generates an oscillating signal that is amplified by a class D amplifier that then drives the exciter coil. Class D amplifiers are noted for their high efficiency, which reduces power consumption. The reference coil and 20 sensing coils pick up the signal from the remote field generated by the exciter coil, and the lock-in amplifiers detect and analyze the signals. The results are digitized and sent to the RFEC Supervisor computer that stores the data on a Secure Disc (SD) memory module. The Supervisor controls all RFEC modules operations and communicates with the sensing module and the robot supervisory computer via the CAN bus. It uploads the inspection data to the supervisory computer for transmission to the robot operator(s) and receives and transmits commands and status information.

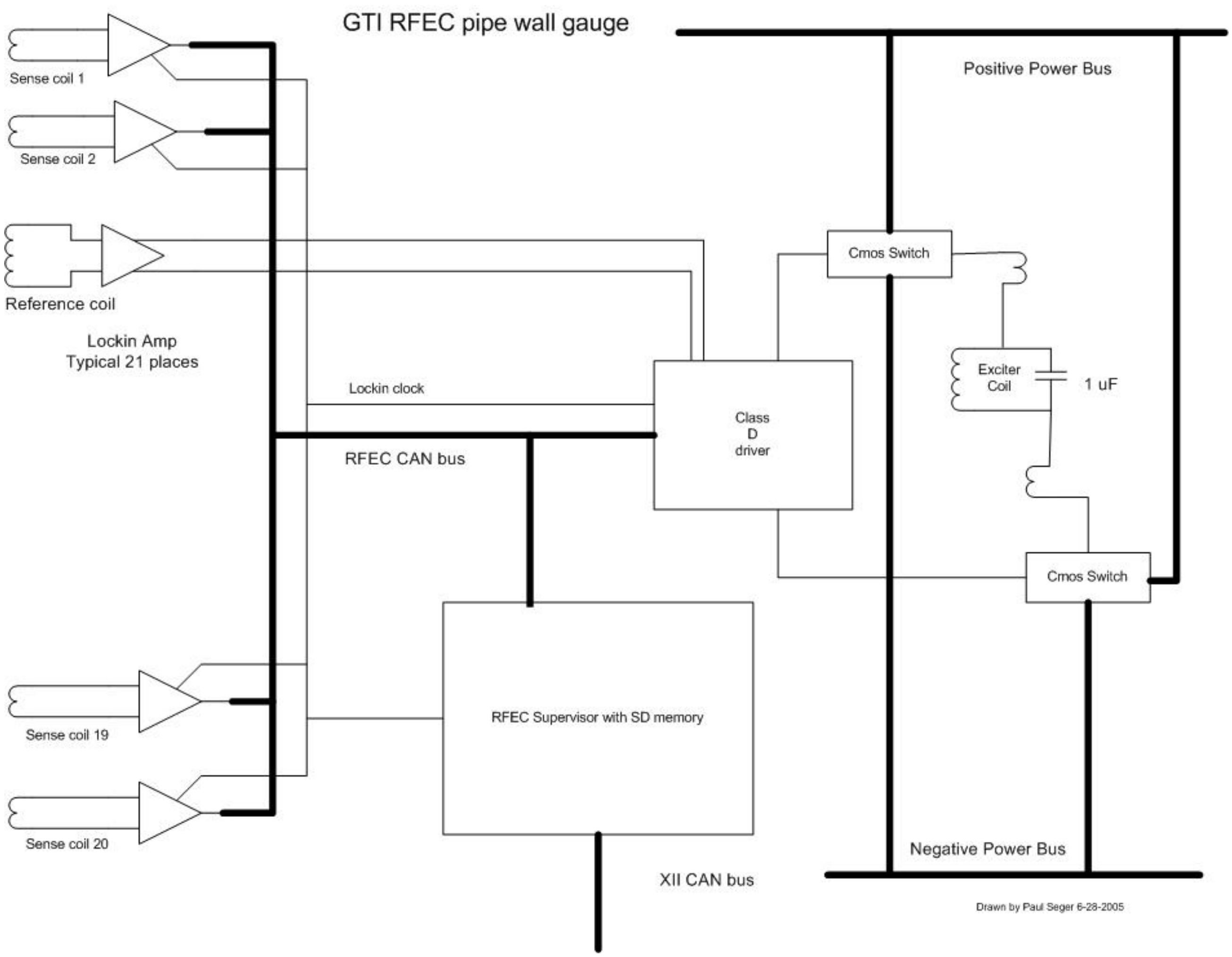

Figure 3: Electronics Diagram for RFEC.