Project Title: Energy harvesting for IoT Technology within the Oil and Gas Industry in Oman

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Sources of Fund: self

Research Field(s): Energy harvesting

Summary and Problem Statement:

In oil and gas industry, bulky wired-cabling is not a good choice to monitor processes and communicate the information within the whole system. The energy industry is currently looking towards embracing IoT technology in almost all its operations, from monitoring well production to predicting when its gear will need maintenance. A new report produced by McKinsey Global Institute estimates that linking the physical and digital worlds could generate up to $11.1 trillion a year in economic value by 2025 [1]

This M2M (Machine to Machine) direct communication, between sensors and actuators through computing systems, can be achieved through Internet Of Things (IoT) and wireless Sensor Networks (WSNs). Today many companies are developing wireless networks for various industrial applications such as Gas and Oil industry. EE publishers produced a recent article in 2019 titled "Wireless monitoring to modernise the oil and gas industry" where it stressed Industry 4.0 trends in oil and gas industry through IoT and WSNs and how these wireless technology can significantly affect the industry [2].

Wireless sensing technology is ideal for the oil and gas industry for the many reasons such as; condition monitoring, production optimization, improving safety, reducing cost of wired devices [3]. In wireless sensing scenarios, hundreds or even thousands of sensors are deployed in a remote area; i.e., production monitoring of an oil field, integrity monitoring of a long oil/gas pipeline infrastructure or condition monitoring of a huge plant. There many challenges faced while using conventional batteries to provide operating power to wireless sensing/control nodes are [3]:

1- Limited life time of the batteries
2- Need to continuously replace batteries at thousands of points
3- Batteries replacement could be a very time consuming task and even uneconomical and unmanageable. In some applications, replacing batteries is not practical.
4- Huge maintenance effort would be required to replace or recharge the batteries of these sensors.
5- Sensors' battery replacement for pipelines buried in soil or in water, or in a hazardous environment where could require the shutdown of a plant and operation.
6- In addition, in remote and difficult to access locations like subsea oil fields, battery replacement or recharging could be very expensive.
7- The performance and reliability of conventional batteries (primary/rechargeable) drastically degrades in harsh environments, which are very common in the oil and gas industry.
8- Relative big size of battery compared to other devices in the node (e.g. sensors, and actuators)

Self-powering those devices can resolve all the previously mentioned issues completely.

The pipeline infrastructure of thousands of kilometers also possesses very small magnitude of vibrations at the pipeline surface. The pipeline carrying liquid (oil, water), gas or a multiphase flow can exhibit vibrations. The nature of flow-induced vibration in a pipe conveying fluid is a broadband frequency vibration. The turbulence-induced vibration generates random pressure

fluctuations around the inner surface of the pipe forcing it to vibrate. In case of plants and refineries, line powered machinery are excellent vibration sources to harvest from. They have a repeatable frequency component of 60 Hz (line power frequency in The Sultanate of Oman) or 120 Hz (2X line power frequency). Mechanical energy harvesting techniques can be used to convert the mechanical vibrations to electrical energy. One example is a piezoelectric- or electromagnetic-based energy harvester, tuned at the structural vibration frequency of pipeline or process equipment. The harvester should have sufficient bandwidth and be able to operate at a range of frequencies. The power generated by the harvester can be utilized for a number of sensing applications including equipment condition monitoring, pipeline integrity monitoring and production monitoring. Fig. 1 shows pressure, flow, temperature and level sensors that gather important industrial data and their location within oil and gas industry [4]. The aim of this project is develop vibration energy harvester to power these nodes.

Keywords: Electromechanical systems, power generators, Energy scavenging, Piezoelectric energy

Objectives: At this stage, it is clear that there are many issues needed to be tackle to enable fully autonomous and maintenance free wireless sensors for various applications in the oil and gas industry, as well as to provide the oil and gas industry with continuous source of energy. Energy harvesting can be used for providing reliable and long-term power for sensors by scavenging various ambient energy sources.

The objectives of this project can be classified into three major areas: Technological, socio-economic, and knowledge transfer objectives.

Technological Objectives:
1.To make a significant contribution to wireless technology in oil and gas industry by self-powering Wireless Sensor Networks (WSNs).
2.To numerically model the self-powered system using coupled finite element software
3.To utilize the free mechanical vibration energy in oil and gas industry and covert it to useful electrical energy to power WSNs
4.To optimize the energy harvesting devices to best suit gas and oil industry
5.To fabricate an energy harvesting prototype and to evaluate its performance and carry out necessary improvement

Tentative Methods of Approach:

1- Investigating and measuring the ambient mechanical vibration (e.g. level and frequency of vibration and the broadband range)
2- Geometrical design of the vibration structure using ANSYS Workbench or COMSOL.
3- Design of integrating vibrating element and energy harvesting element for power

production
4- Design optimization of the vibrating structure and the harvesting element (through e.g. material selection, shape, dimensions,..etc) for maximum power output.
5- Design optimization for broadband vibration frequencies
6- Design and development of experimental setup
7- Carrying tests and measurement at SQU (Mechanical and Industrial Engineering department)
8- Carrying tests and measurement at SQU (Mechanical and Industrial Engineering department) for the MEMS device.
9- Analyzing results and suggesting improvements
10- Results documentation

Required backgrounds and skills

Backgrounds:

Mechanical, electrical, or electronic engineering degree. Or degree in physics

Computing Skills:

Other requirements:

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