Electric Power Sensing for Demand Response

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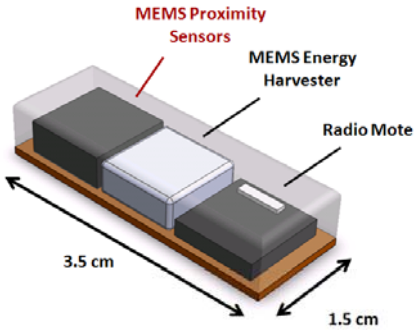
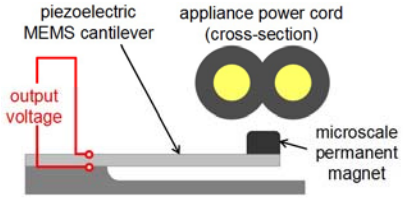
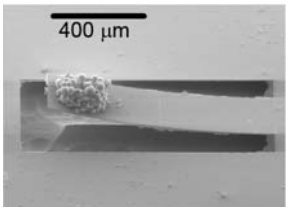
Vision

Upcoming Smart Grid initiative necessitates the distribution of thousands of sensors to monitor the operation of the future U.S. power grid. Our group is developing small and inexpensive self-powered sensor modules that can be non-intrusively deployed (simply attached to equipment) throughout the grid (in residential/commercial, distribution and transmission circuits) to wirelessly monitor current, voltage, as well as other operational and diagnostic parameters



MEMS Current Sensing





Sensor operation:

•Permanent magnet couples to the magnetic field surrounding an AC current carrier

•Piezoelectric cantilever transduces the force on the permanent magnet to an output voltage

Sensor does not require power supply and does not need to physically encircle conductor

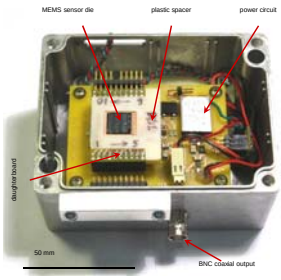
•Apparatus designed to support first-generation MEMS current sensors for in-depth testing of device response and improved duty cycle from initial tests.

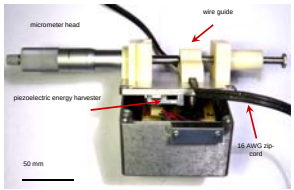
• Commercial off-the-shelf (COTS) packaging utilized where possible for testing efficiency; resulting device is large but acceptable for bench top purposes.

•A micrometer head was utilized for precise positioning of wire to be measured.

•Package used off-the-shelf electronics where possible; amplifiers and power-circuitry are low current but not specially optimized. Testing board includes passive filtering but no onboard processing.

•Power supplied by either a 9V battery or a prefabricated piezoelectric energy harvester

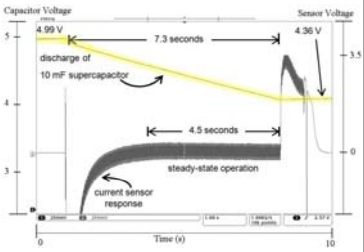


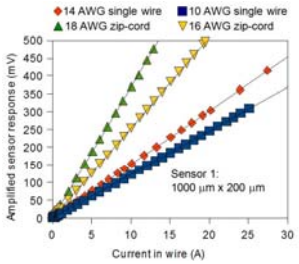


•Parasitic capacitances and other non-idealities prevented expected amplifier gains, but in a quantifiable manner, allowing unamplified voltage and device capacitance to be calculated from results.

•In tests that incorporated energy harvesting and a super-capacitor, it was found that by charging the super-capacitor intermittently to a set voltage large enough to drive a radio chip it was possible to operate at a 16% duty cycle.

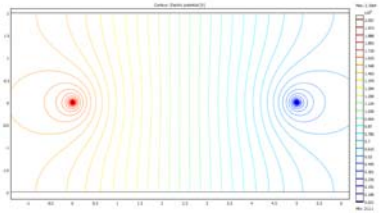
•Initial testing of a limited number of sensor devices show a high degree of linearity across a 0-30A range of currents. Substantial additional characterization of a large number (~30) of sensors across a wide range of currents (0-200A, 10-200Hz) are planned

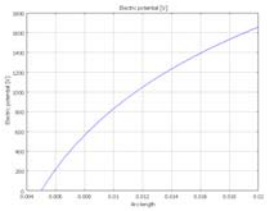


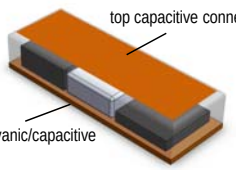


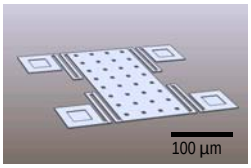
MEMS Voltage Sensing

Passive MEMS-based electric field sensors that can be placed e.g. onto power lines to instantaneously measure both line-to-ground, and line-to-line voltage.





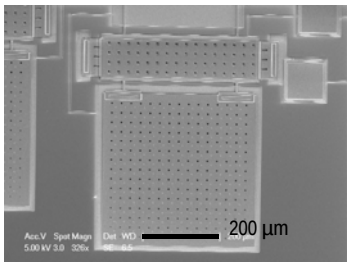




(top-left) FEM modeling of electric potential between two overhead transmission line wires (1 cm in diameter, 5 m separation) with a potential difference of 15 KV. Note that the potential changes rapidly in the proximity of the wire (top-right). Capacitive pickup on the surface of the sensor module (bottom-left) channels charges to a MEMS sensor (bottom-right).

MEMS Power Sensing

We have also fabricated a MEMS power sensor, which we are currently testing.



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