MEMS Proximity Voltage Sensing

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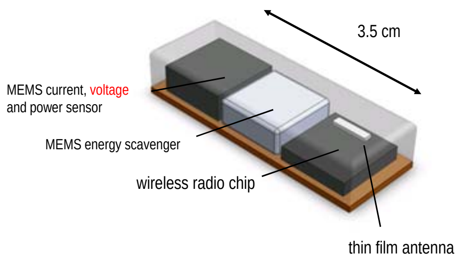
Goal

Our research goal is to develop a self-powered proximity-based MEMS voltage sensor that can be used to determine the line-to-ground or line-to-line voltage of overhead power transmission or distribution lines. The sensor will be embedded in a self-powered wireless sensor module (see Fig. 1 below).



Background

The electric fields near overhead transmission or distribution wires are able to couple significant voltages across a capacitive circuit or a MEMS component. This effect is amplified in the vicinity of the overhead wires due to the large increase there in the gradient of the electric field.

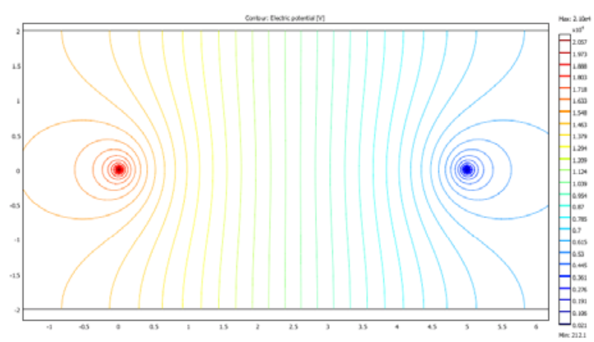


Fig. 2. FEM modeling of electric potential between two overhead transmission line conductors (1 cm in diameter, 5 m separation, with a potential difference of 15 KV).

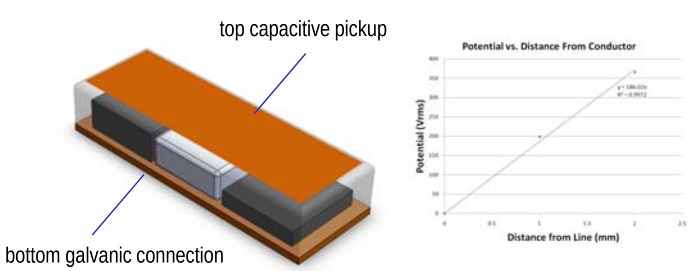


Fig. 3. (Left) We intend to use the package of the sensor module attached to the power line conductor as part of the capacitive pickup for the sensor, in order to maximize its capacitance and hence sensitivity. (Right) Voltage referred to that of the conductor supporting either a solid-state capacitive sensor or a MEMS sensing device. (Voltage values obtained from FEM model in Fig. 2.) Note that a large potential difference exists over relatively small distances from the supporting conductor, and that the potential difference varies nearly linearly close to the supporting conductor.

Sensor Design

We are developing two different sensor designs, one based on solid-state microelectronic amplification of the capacitive signal, and one based on MEMS, in which the micromechanical motion induced by the local electric field is used to determine the potential at a known distance from the supporting conductor. Some of these commercial solid-state devices are quite sensitive but have shortcomings that we're addressing: their response is typically quite nonlinear, and there is no simple means for making the devices self-calibrating.

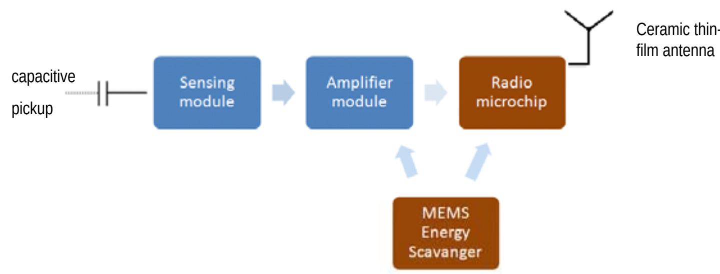


Fig. 4. Schematic of the solid-state amplification sensor concept.

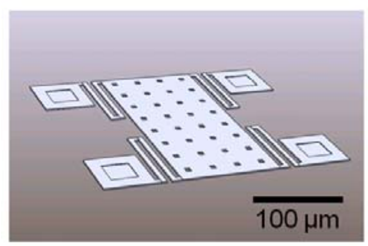


Fig. 5. Proposed MEMS approaches include use of a MEMS cantilever connected electrically to the broad top capacitive pickup of Fig. 3, and use of the MEMS component sketched above, whose amplitude of motion when activated by the local electric field will provide a measure of the line-to-line voltage. Self-calibrating means have been conceived but not yet implemented.

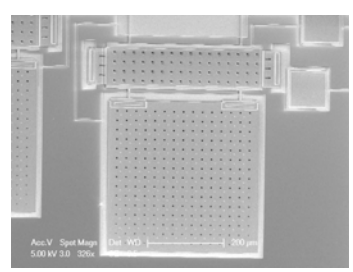


Fig. 6. Fabricated MEMS power sensor that will be used to test the principles behind the MEMS voltage sensing.

Future Steps

•Complete design and test (in our 5 kV facility) improved solid-state voltage sensor (linear response, self-calibrating)

•Complete analysis and modeling of MEMS voltage sensor designs; fabricate and test.

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