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ABSTRACT - Flexible flag-like panels composed of flexible piezo-electric materials (PVDF) affixed to a nonpiezoelectric core are described which generate electricity when positioned to flap in the wind. This paper describes several steps taken to maximize the output power at moderate wind speed.

I. BASIC CONCEPt

Figure 1 shows the basic concept and Fig. 2 details the construction of the piezoelement. The piezoelement dimensions are determined using an approximate theory relating the dimensions to the onset, at a specific wind speed, of the aerodynamic instability (Klein-Helmholtz instability) that causes the flapping. [1]

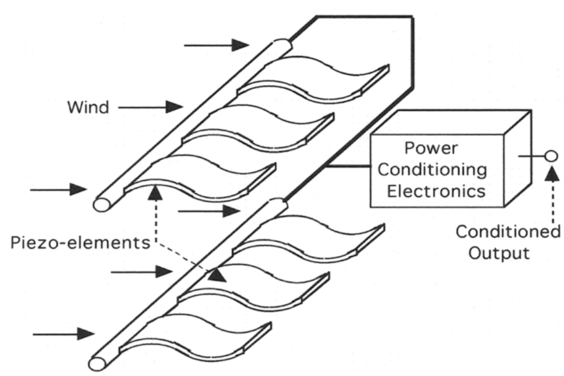

Figure 1. Concept diagram for generating electricity from the wind using flexible piezoelectrics.

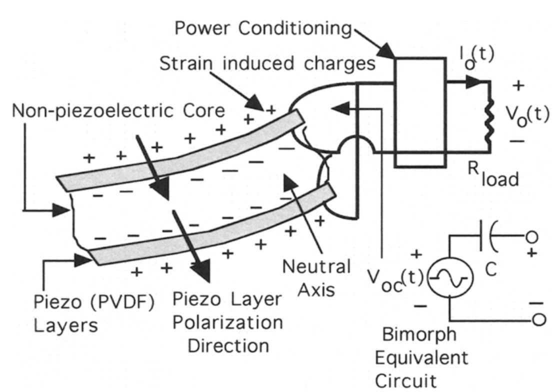

Figure 2. Cross-sectional view of a bimorph piezoelement.

II. AERODYNAMIC CONSIDERATIONS

Different induced airflow patterns around the piezoelements were explored to see what arrangement produced the strongest flapping at the lowest incident wind velocity. These included free incident laminar flow indicated in Fig. 1, a short duct-like arrangement, shown in Fig. 3, for inducing strong shear layers around the piezoelement, and an induced vortex street generated by a bluff body placed at the location of the piezoelement anchor rod. Fig. 4 shows the open-circuit voltage generated by the same piezoelement flapping in both the laminar flow and shear layer geometries.

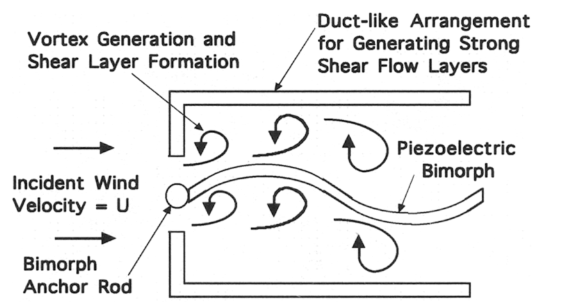

Figure 3. Use of duct-like structure to generate strong shear layers in air flow around piezoelement.

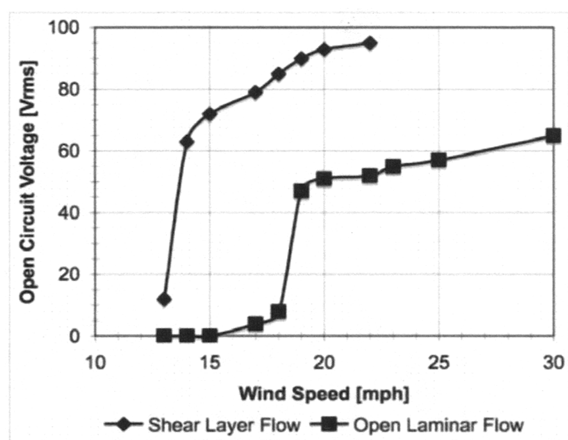

Figure 4. Open-circuit voltage versus incident wind speed for single 8.5x12x0.015 inch piezoelement.

When two wide piezoelements, 16x12x0.015 inches, piezoelements are spaced about 23 cm apart, one above the other as shown in Fig. 1, the elements flap in phase. The onset of strong flapping occurs atabout 14 mph, nearly the same as that shown in Fig. 4 for the shear layer flow geometry.

III. Effect of Added End Weights

Weights attached to the free end of the piezoelement increases the output power compared to a weightless end (see Fig. 5). The added weight also lowers the flapping frequency.

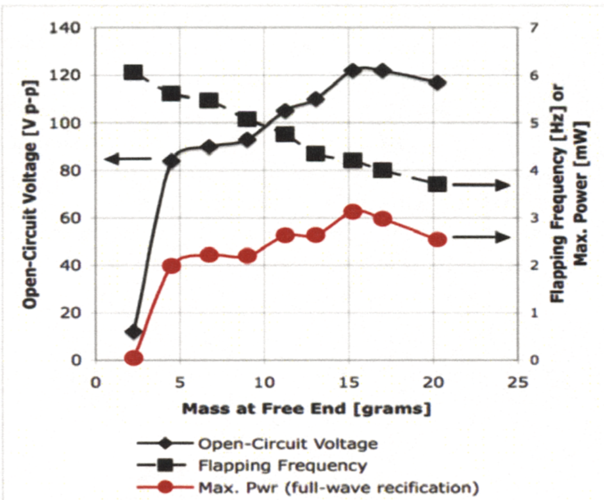

Figure 5. Output power versus mass loading at the free end of a bimorphs in a 15 mph wind.

IV. Power Extgraction circuits

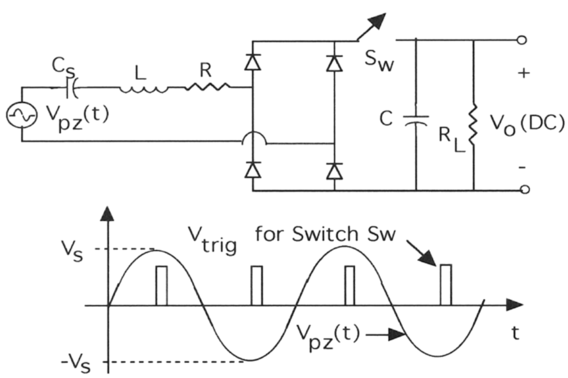

Figure 6. Synchronized switched harvesting inductor circuit for extracting energy from the piezoelements.

A full-wave rectifier is the simplest power conditioning circuit for extracting power from the piezoelement. However the synchronized switched harvesting inductor circuit [2] shown in Fig. 6 extracts several times more power. Fig. 7 shows the output power versus load resistance obtained from an 8"X11"X0.02" piezoelement flapping at 5 Hz in an 18 mph wind using the shear flow structure of Fig. 3

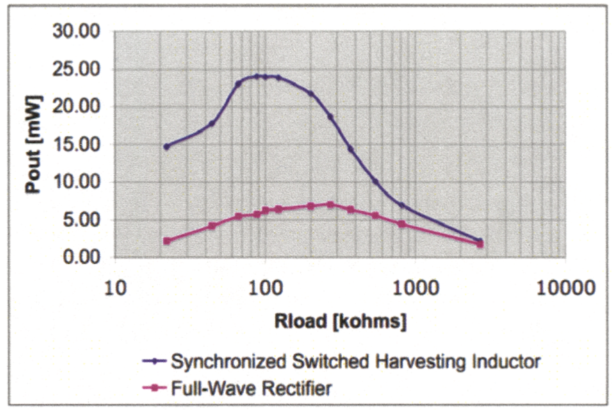

Figure 7. Output power versus load resistance.

V. Improved Piezoelectric Elements

Simple calculations indicate PZT-based macrofiber composites (MFCs) will produce 25 times more power under identical conditions than a comparable PVDF element. We are currently acquiring sample MFCs to test as piezoelements.

VI. Conclusions

The piezoelements are quite durable. Bimorph elements of the same size discussed earlier have been tested to over two million cycles with no significant loss in performance. The scheme is mechanically simple and lightweight. The system has potential applications such as wireless sensors and wireless networks amd general purpose off-grid applications.

Acknowlegements

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References

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