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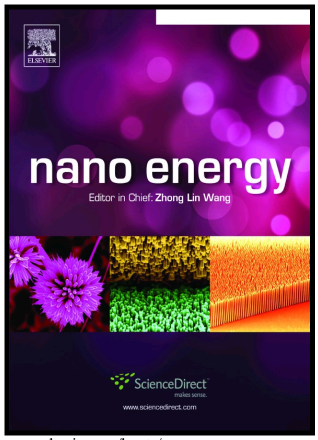

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Power computation for the triboelectric nanogenerator

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Abstract

We consider, from a mathematical perspective, the power generated by a contact-mode triboelectric nanogenerator, an energy harvesting device that has been thoroughly studied recently. We encapsulate the behaviour of the device in a differential equation, which although linear and of first order, has periodic coefficients, leading to some interesting mathematical problems. In studying these, we derive approximate forms for the mean power generated and the current waveforms, and describe a procedure for computing the Fourier coefficients for the current, enabling us to compute the power accurately and show how the power is distributed over the harmonics. Comparisons with numerics validate our analysis.

1 Introduction

Triboelectric nanogenerators (TENGs) have received considerable attention recently as potential candidates for energy scavenging [1, 2, 3, 4]. These devices have been shown to convert mechanical energy into electricity in applications such as energy harvesting and self-powered sensors [5, 6, 7]. Furthermore, TENGs have many advantages over existing energy harvesting technologies [2, 3, 5, 7, 8], such as low cost, simple construction, relatively high power, flexibility and robustness.

The contact-mode triboelectric nanogenerator is the most commonly used TENG architecture owing to its simplicity and output performance [8, 9]. Typically, it consists of two triboelectric plates, at least one being of dielectric material, each attached to an electrode. When the plates come into contact, one becomes positively charged and the other, negatively. (Static electricity produced by friction is a well-known example of the same effect.) We feel that it is timely to discuss, from an applied mathematical point of view, the power produced by a TENG, whose construction is described in detail in for example [1, 4, 8].

A related device, a piezo-electric generator designed to harvest energy from the heartbeat, is described in [10], but its mathematical modelling, at least from the point of view we take here, is straightforward and so of less interest.

In this paper, we consider the most common configuration — two metal electrodes, each with a layer of dielectric attached — in order to assess its power output characteristics. Our starting point is the ordinary differential equation (o.d.e.) that describes such a TENG connected to a load resistance R. Our main assumption is that the TENG is being driven periodically at a frequency ω, that is to say, the separation of the plates varies periodically with time. We then adopt a circuit theory approach,