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SMP Biotechnology and Bioengineering

Models for Elasto-electricity and PhotoVoltaic in a Micro Power Plant

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Publication Dates

Received date: January 15, 2022

Accepted date: February 15, 2022

Published date: February 17, 2022

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Citation

Strömberg LJ-T (2022) Models for Elasto-electricity and PhotoVoltaic in a Micro Power Plant. SMP Biotechnol Bioeng 1: 1-5

Abstract

Models for dynamic capacitors in the WFB from [1] are derived. The analysis is based on observations and experimental results. On the provided AC-power background, an NPN-Sun- Catcher were attached, and here, this is evaluated in terms of one-way elasto-electricity and Photo-Voltaic.

Keywords: Micro-Power Galvanic Battery; Components; Alternating Current; Npn-Diode; Solar Power; Pv; Amplification; Capacitor; Solitonial; Differential Geometry; Attraction Field; Foil; Wire; Piezo Electricity; Electro-Dynamics; Stress States

Introduction

The experiments in [1] will be analysed in terms of various modeling. With AC-power, it is possible to magnify Voltage and to collect current with e.g. elastic wires and Sun Catchers, e.g. PhotoVoltaic, PV. In the present paper, a component for the latter will be focused on, as well as a method to obtain AC in a pot plant battery.

With knowledge of the electric output, materials and geometry for the construction, governing equations are proposed. In mechanics, such are provided in terms of constitutive equations, and part of that framework will be exploited.

The measured current and voltage oscillate between zero and a top value. The frequency andamplitude depend on

- the geometry of the pot with electrods
- wind velocity and sunshine
- the structural electro-mechanics in the components

Technically, these properties are input, and the output is Voltage and Current in the circuits. Here, we will consider interior models for a WFB and a Sun Catcher, Figure 1, aligned to the electric circuits [1]. Hence, the input will be mainly electric; then added by the electric responseto sunlight and wind motion.

Figure 1: Wind Flower Beam (WFB) and Sun Catcher (the round metal Cup with content) in thecircuit of a battery

Models for dynamic capacitor in WFB

The functional dependency for the output can be derived from differential equations; e.g. a damped forced vibration. Such an equation will be extracted from a system of integro- differential equations.

Modeling into a differential equation of forced vibrations

The wrapped foil accumulates the loading, as a conductor. This varies with time, since the foil moves.

The input and output are cast into formula language:

i,t+ci = F(int i dt) + K   (1)

where i is the current, c is a constant F is a function of cumulative load described as an integration of i and K is the local curvature. Refining into details; K depends on wind load input, elasticity and material. The resulting time dependencies are due to wind speed, size of the devices and the capacitance of the foil with two cupper line ends.

Differentiation and linearisation give a damped harmonic oscillator with input K,t . Since no visible or detectable reversed action, the input is assumed as a Dirac pulse, γ.

Remark: Harmonic oscillators (with optional input to forced vibrations), are solutions to motions in piezo-electricity models, [2].

Invoking details on e.g. spatial distributions for loads and densities will give a nonlinear model with more indeterminance, but also possibility of information for the frequencies and other responses. In an application where several entities are put together in a matrix, (as e.g. in a PV- panel and car-batteries), the ensemble properties (due to periodic boundary conditions) will probably also rule the the overall behaviour, e.g. into an oscillation for the electric current.

Therefore, a more detailed material model will not be outlined. Instead, the ramifications of ageneral nonlinear system will be scrutinised.

Since there are loadings that travel in the foil and reach the cupper lines where they are measured as current, a solitonial model will be analysed.

Attraction field solutions to a weighted Solitonial model

A first order system for the solitonial [3] reads

$y'(x-ct)=3f^2+cf+A$ (2)
$f'(x-ct)=y$ (3)

where f is a function of x-ct, c being a constant parameter

To emphasize dependency on the argument, the system will be multiplied with x-ct on each equation. Then a differentation with a wedge product is applied. This results in the following system of equations

$dX \wedge dy=X(6f+c)df \wedge dX$ (4)
$dX \wedge df=X\, dy \wedge dX$ (5)
where X=x-ct and ^ is a wedge product, c.f. [4].

Remark: The same result, except for some signs, is obtained with a linearised differentiationand bilinear products.

Proposition: By combination of (2)-(5), the solution A=0, $f=-c/(6X^2)$ is derived.

Remark: In a moving grid, c.f. e.g. [5,6], with velocity c, or for constant t, the solution is similar to Coulomb attraction in vicinity of loads or charged particles. These are at periodic locations x, when t is proportional to integers.

Sun Catcher

The Sun Catcher, Figure 1, may collect both from photons and by heat perception. The foil & the Cup act as a capacitor. Before the foil, there is a prestrained wrapped wire. If this deformsat heat expansion, the resistivity is changed, which might add loads and current to the device. For this, we will consider modeling of piezo-electricity [7], in a generaliserad interpretation.

The equation reads

$e=S\, s3+d31E$ (6)
$D=d31s1+kE$ (7)

where e is strain, s1 and s3 are stress components [N/m^2], E is applied electric field [V/m], D iselectric displacement [C/m^2], S, d31, and k are material constants.

Remark: Input action from sunlight is identified with s3 and the inplane stress-response is s1

To extract dependencies, a case where the strain is zero will be analysed. With e=0 , the electricinput from the lines can be eliminated and the amount due to Solar energy reads

$D=d_{31}(s1-s3kS/d_{31}^{\ 2})$ (8)

Remarks: An interpretation of the right side is that it may be due to both photons (s3) and inplane mechanical deformation, e.g. bending (s1). The factor on the out-of-plane respons shows similarity with volume fraction for increased densities of 3d -particles in a plane flow.

Assuming that s1 and s3 are principal stresses, s1>0, s3<0 and defining a rescaled area for either of the stress components, or for certain values of parameters; the right side will be the maximum shear stress. The latter will be cast into a theorem.

Theorem: For plane stress where 1,3 are principal directions, s1>0, s3<0, the maximum shear stress $\tau=(s1-s3)/2$, and located in a system rotated $\pi/4$ from 1,3. When the ratio $kS/d_{31}^{\ 2}=1$, the right side in (8) is proportional to τ.

Proof: The results are given by the algebra and geometry for stress states.
The structure of the wire in the cup, Figure 1, is twisted and the measured resistance varies when subjected to torsion. In general, the response is unstable, such that it moves snapthrough/in buckling. This may be beneficial to collect current.

Preliminaries: Assuming that the strain is proportional to E, a state of simple shear;$s1= \tau$, $s3= -\tau$, will be analysed.

Proposition: e=CE and simple shear is in agreement with a state where the applied electric fieldfulfils the equation $E= \tau S/(d31-C)$

Remarks: For a Sun Catcher or wire subjected to heat expansion, the shear stress may be considered input as the respons of the material to sunlight. Then, a generalised interpretationof E may include gain, and not only input.

A constrained wire moving at wind load or in a water stream, also responds in shear.

Conclusion

In the present paper, the electrodynamic and PhotoVoltaic devices in Figure 1 were analysed.The methods used were

- modeling of accumulated loads
- differential geometry for Solitonials
- generalised Piezo-electricity

The results gave

- an oscillating current
- Solitonials coexisting with attraction field sources
- relations between electric field measures & mechanical stress components

In operation, the Sun Catcher Cup was found to amplify the Current 5.7 times. It remains to quantify the contribution from each part i.e. how sunlight multiplies the load density in the foil and metal or otherwise increases the value inthe Cupper Lines, and the part due to heat expansion and 'piezo-electricity' of the wire.

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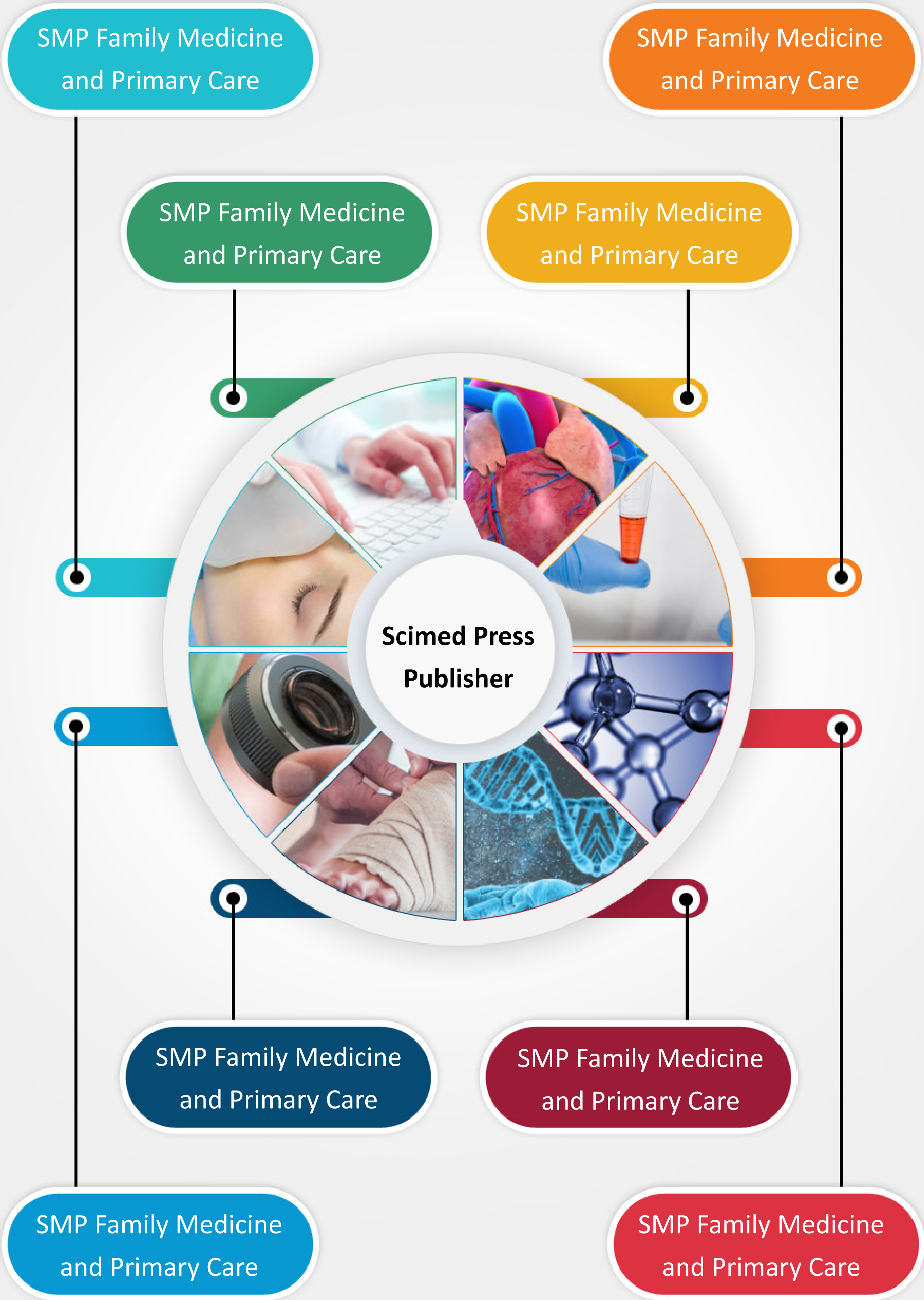
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