On forward and reverse coupling of vibrating piezoelectric energy harvesters

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ABSTRACT

Energy harvesting, is the conversion of ambient energy present in the environment into directly available electrical energy. Due to the small amounts of energy available in the surrounding ambient, typically, energy harvesting is applied to supply small-scale, low-power electronic devices.

One of the most studied and implemented phenomenon is the piezoelectricity effect of materials. A piezoelectric patch connected to a structural thin beam can separate charges due to a mechanical stress applied to the beam and, thus, to the piezo-material. This is called forward effect and it exploits the piezoelectric material as a sensor. If the piezoelectric material is used as an actuator, by applying a current a deformation on the patch is obtained and this is called the reverse effect.

Based on literature, the piezoelectric patch applied to a cantilever beam or similar structures is typically modelled in the mechanical side with inertial, equivalent elastic and dissipative terms, due to the electric coupling and, on the electric side, by a current generator and an impedance constituted of resistance and capacitance.

In harvesting applications, exploiting the direct effect, the mechanical action generates an electrical effect. However, the reverse effect is present and influences the dynamics of the mechanical part of the system and its effects cannot be neglected. For a complete description of the system, in particular in harvesting devices, taking into account the coupling of the two effects is required.

It is worth noting that the input energy of the electrical part, the converted energy, is different from the energy outgoing the mechanical system due to the piezoelectric coupling. As the forward effect is typically lower than the reverse effect, the input energy in the electrical part, namely the maximum recoverable, is lower than the energy outgoing the mechanical part. An important note about the meaning of the electromechanical coupling coefficients and on the ability of the considered model in describing the energy conversion is necessary.

Based on these concepts, the paper is focused on analytical and experimental validation of forward and reverse effects in piezoelectric patches applied to cantilever beams subject to imposed kinematics. An experimental validation confirms the strong coupling characteristic of this mechanical-electric system.

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