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SEC2T (Renewable Energy and Energy Harvesting)

Topic - Piezoelectric Energy

Introduction:

The piezoelectric effect converts mechanical strain into electrical voltage. This strain can come from many different sources. Human motion, low-frequency seismic vibrations and acoustic noise are a few examples. The piezoelectric effect can be implemented to harvest mechanical energy from walking. This energy can be converted into useful electrical energy that can be used to power wearable electronic devices such as sensors and Global Positioning System (GPS) receivers. Piezoelectric energy harvesting can also be used to power some consumer electronic devices directly such as cellular phones, two-way communicators and pagers.

Piezoelectricity is the ability of some crystals to generate an electric potential in response to an applied mechanical stress. When the crystal is under mechanical stress (e.g. by compression or expansion), the electrical charge of the dipoles become aligned, leading to a net electric polarization. This is responsible for the electric potential across the crystal and provides a convenient transducer effect between electrical and mechanical oscillations. If mechanical vibrations are applied to such crystals, they will respond with an electrical oscillation output which can act as a source of power. These effects can be exploited to harvest energy from disturbance sources. For the electrical power to be useful, an additional electronic circuit would be required to rectify and regulate the power output in the most efficient way possible.

Principle of Operation:

Recently four proof-of-concept Heel Strike Generators (Fig. 1) were developed for converting the mechanical energy of walking into electrical energy. The Heel Strike Generator uses Lead Zirconate Titanate (PZT-5A) piezoelectric

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materials to transform mechanical energy into electrical energy. The input mechanical energy is transformed into electrical energy through four PZT-5A bimorph stacks. Hence the Heel Strike Generator has four phases of electrical energy generation. The Heel Strike System uses a power electronics circuit to extract, store and regulate the electrical energy output from the four phases and converts it into a 12 V DC pulse.

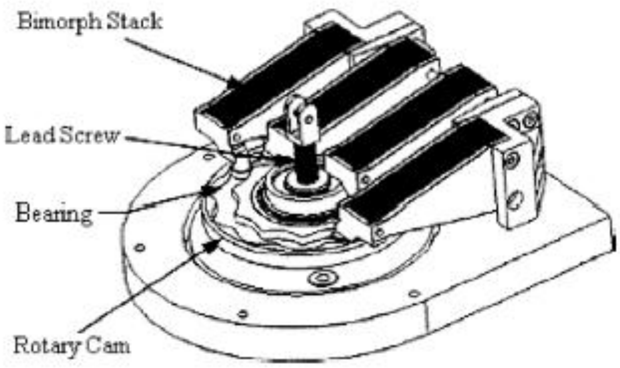

Fig. 1

When a user steps down and compresses the Heel Strike Generator, a lead screw and gear train convert the linear motion into the rotation of a cam, where the rotating cam causes the PZT-5A bimorph stacks to deflect sinusoidally. The stacks are arranged in such a way that they oscillate 90^0 out of phase with one another, recycling most of the elastic energy stored in the bimorph crystal stacks. Each sinusoidally oscillating PZT-5A bimorph crystal stack produces an oscillating voltage that is rectified and regulated by a power electronics circuit that is separate from and connected to the Heel Strike Generator (Fig. 2). The power electronics circuit takes in the AC voltage signals from each phase of the Heel Strike Generator rectifies them and produces DC pulses that charge a storage capacitor. Any stored charge in the capacitor is then discharged through a DC–DC converter, which converts that stored energy into a regulated 12 VDC output pulse.

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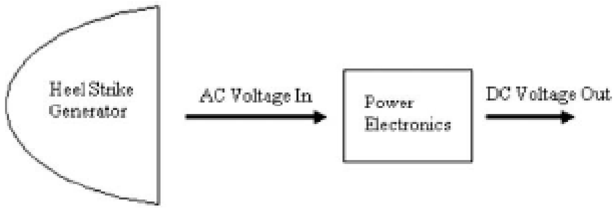

Fig. 2

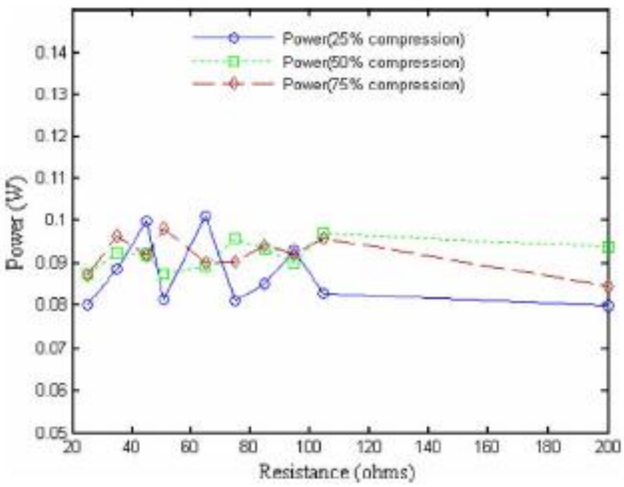

Fig. 3

Results and Evolution:

The results of the test and evaluation are displayed in Fig. 3 which shows the average power (power averaged over a DC output pulse or average power produced per compression) produced by the Heel Strike System during each compression at each electrical resistance. Based on the power data measured, the average power over each compression of the Heel Strike System appears to be steady and independent of stroke compression and external resistance. This makes sense since, as the applied electrical resistance increases the current draw should decrease and the pulse time is known to increase making the energy dissipated in the resistor over the pulse time nearly constant. Also the power electronics circuit is designed to rectify the AC voltage signals from the piezoelectric stacks, use those rectified signals to store charge in a capacitor and then periodically discharge that capacitor through a DC–DC converter such that a 12 V DC pulse is always produced at the output of the power electronics. Any excess charge produced from increased compressions is likely to be discharged through the resistor elements and/or ground of the power electronics circuit.

Topic - Electromagnetic Energy

Linear Generator:

Linear electric machine with reciprocating mover is of great interest now especially as a linear generator with reciprocating mover which is used together with free-piston engine. High power density in such an electric machine is achieved by the use of permanent magnets and fractional slot concentrated armature winding which together provide a big challenge to designer of such machines. In order to make an initial design, perform optimization procedure and evaluate resulting characteristics several mathematical models of different level of complexity were developed. Sizing equations are based on general equations of balanced electric machine, while main mathematical model takes into account real winding diagram, different length of armature winding and moving inductor and even rectified load. This main model is an analytical one, so it can be used for optimization purposes as it provides very fast calculations. The third model of high discretization level is based on FEM analysis and it allows to obtain generator output characteristics with high accuracy in order to exclude or minimize prototyping stage of design process.

Carbon Capture and Storage:

Carbon capture and storage technology captures carbon dioxide (CO_2), then compresses and liquefies it, and finally transports it by pipeline or in tankers to safe and permanent storage in geologic formations. Some of this technology is

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proven and has been utilized by the oil industry for enhanced oil recovery. However, it has not been adequately demonstrated on large-scale coal-fired power plants as components of integrated clean energy systems. CCS technology for utilization at new, large power plants offers the greatest potential for CCS. CCS can also be used to mitigate CO_2 emissions from other large, stationary source industrial applications.

Carbon Capture: Technology utilized with new large coal plants can reduce emissions by 80% – 85%. However, capture technologies require additional energy, which reduces overall efficiency. Earlier conversion loss estimates of up to 13% have been revised (IEA 2004) down to eight percentage points in existing coal-fired power plants, and to four percentage points in future integrated coal gasification combined cycle (IGCC) designs.

Transportation: The transportation of CO_2 from the source point to the storage site is comparatively inexpensive but substantial infrastructure needs to be built. The mode of transportation (pipeline, tanker, truck, ship) of the CO_2 in gaseous, liquid or supercritical state depends on the pressures and volumes to be shipped, and on the distance to the storage site. A network linking various source points to a storage site would be an asset in regions where storage sites are not proximate to the sources. It remains to be determined how such networks can be sited, financed and operated. At present, 3000 km of dedicated, land-based CO_2 pipelines are in routine operation (IEA 2004).

Storage: Potential underground depositories for CO_2 are plentiful. Global capacities in saline formations are estimated at 1000 to 10000 $GtCO_2$ and in depleted oil and gas fields at 1100 $GtCO_2$. This corresponds to 90 – 480 years of current world emissions at 23 – 24 $GtCO_2$/year. Moreover, CO_2 can also be stored in abandoned or unminable coal beds or glacial clathrates. At present, more than 33 million tons of CO_2 are being captured and stored in over 70 projects (IEA 2004). Most are experimental, but there are large-scale commercial projects in operation in In Salah (Algeria), Weyburn (Canada), the North Sea (Sleipner), and forthcoming in the Barents Sea, Gorgon (Australia), Gassi Touil (Algeria) and other fields. As noted earlier, CO_2 is injected

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commercially into oil reservoirs for enhanced oil recovery (EOR) in many parts of the world. Storage-related issues include a reliable assessment of storage capacity; an increased understanding of CO_2 trapping, migration and impact on ground water; and prevention, monitoring and remediation of leaks. Public concern about the risk of leaks needs to be addressed at an early stage by pointing to the present safe storage of millions of tons of CO_2 and the elaboration of designated regulatory regimes. Additionally, issues of short and long-term liability need to be discussed and settled.

Socio-economic Assessment:

The choice of energy systems, like any other feature of major social organisation, is a product of a historical development, of prevailing social value systems and often the role of influential individuals from various layers of society: political decision-makers, industrialists or intellectual figures. As they are not independent of social preferences, one should expect to find different tools available, catering to different positions in the social debate. However, when presented in a systematic fashion, the effects of differences in assumptions become transparent, and the outcome is to exhibit different results as due not just to uncertainty but to specific differences in underlying choices. This would also force the users of these methods to specify their normative positions.

Effect on Environment. However, there are a number of more fundamental social values, associated with basic needs, which are determined by the biology of human beings and thus less subject to modification. Food and (at least in some climates) shelter, an acceptable biological environment (an atmosphere with oxygen, temperatures within certain limits, etc.) and human relations (comprising at least sexual interaction) are in this category. The list may be continued with a number of additional values, which become increasingly linked to the type of society in question. Some such values may be quite basic, but owing to the substantial adaptability of human beings, conditions which violate these values or “needs” may persist without apparent dissatisfaction, at least not on a conscious level. Examples of social values of this type are human

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interaction in a more broad sense, meaningful activities ("work") and stimulating physical surroundings.

The present world is to a large extent characterized by a widespread deprivation of even the basic social values: people suffer from hunger, inadequate shelter, bad health, or they are offered unsatisfying work instead of "meaningful activities", they are surrounded by a polluted environment, ugly varieties of urbanization, etc.

Energy Efficiency. Moving towards energy sustainability will require changes not only in the way energy is supplied, but in the way it is used, and reducing the amount of energy required to deliver various goods or services is essential. Opportunities for improvement on the demand side of the energy equation are as rich and diverse as those on the supply side, and often offer significant economic benefits.

Efficiency slows down energy demand growth so that rising clean energy supplies can make deep cuts in fossil fuel use. A recent historical analysis has demonstrated that the rate of energy efficiency improvements has generally been outpaced by the rate of growth in energy demand, which is due to continuing economic and population growth. As a result, despite energy efficiency gains, total energy use and related carbon emissions have continued to increase. Thus, given the thermodynamic and practical limits of energy efficiency improvements, slowing the growth in energy demand is essential. However, unless clean energy supplies come online rapidly, slowing demand growth will only begin to reduce total emissions; reducing the carbon content of energy sources is also needed. Any serious vision of a sustainable energy economy thus requires commitments to both renewables and efficiency.

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(All the figures have been collected from the above mentioned references)