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Reliability Improvement of Renewable Sources of Wind, Solar and Tidal Energy

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ABSTRACT: It is broadly accepted that renewable energy sources are the key to a viable energy supply infrastructure since they are both inexhaustible and non-polluting. A number of renewable energy technologies are now commercially available, the most noteworthy being wind power, photovoltaics, solar thermal systems, biomass, and various forms of hydraulic power. In this paper, methodologies have been proposed for the purpose of improving the efficiency, increasing the cost effectiveness and minimizing the ecological effects of such energy sources.

KEYWORDS: wind energy, solar energy, tidal energy, exciton fission, bladeless turbine, kites, pentacene, renewable resources, electron coupling

I. INTRODUCTION

Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy resources and significant opportunities for energy efficiency exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid deployment of renewable energy and energy efficiency and technological diversification of energy sources would result in significant energy security and economic benefits. Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services.

As fossil fuels resources have depleted and environmental concern has increased, renewable energy has become a very important engineering sector. It is undoubtedly true that in the future a large proportion of energy used by human race will be derived from a diverse range of renewable resources.

A. Mainstream Technologies

This section explains some of the major sources of renewable energy available to us:

1) Wind energy: Wind is a shape of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and alteration of the earth. Wind flow patterns are adapted by the earth's land, bodies of water, and vegetative envelop. This wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity.

Wind energy as an option to burning fossil fuels, is copious, widely dispersed, clean, produces no greenhouse gases during operation, consumes no water, and uses the little land.

Wind power gives the changeable power which is very reliable from year to year but which has major variations over shorter timescales. It is therefore used in combination with other electric power sources to give a consistent supply.

2) Solar energy: Solar energy is radiant light and heat from the Sun that is collected by employing a variety of technologies such as photovoltaics, solar heat concentrators etc.

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Photovoltaics is a term that covers the transformation of light into electric energy with the help of semiconducting materials that exhibit the photovoltaic effect. A general photovoltaic system engages solar panels, each comprising a number of solar cells, which generate electrical power.

Photovoltaic systems have specific benefits as an energy source: their operation generates no pollution and no greenhouse gas emissions once put in, they show simple scalability in respect of power needs and silicon has large availability in the Earth's crust

3) Tidal energy: Tidal energy is a form of energy that converts the movement of tides into effective power mainly electricity. Tidal energy can take out either kinetic energy from the moving water of large water bodies (rivers, oceans etc.) or potential energy from the difference in height between high and low tides.

The high load factors resulting from the fact that water is 800 times denser than air and the predictable and reliability of tidal energy is more as compared to wind energy and is particularly appealing for electric power generation.

B. Concerns about present-day methods

1) Wind energy: Wind energy is not efficient because wind turbines cannot create electricity at an efficiency greater than defined by Betz' limit, which states that no turbine can capture more than 59.3 percent of the kinetic energy of the wind. Wind turbines most commonly produce some broadband noise as their revolving rotor blades encounter turbulence in the passing air. Some wind turbines, usually older ones can also make sounds (a hum) at a steady pitch. This can be caused by mechanical components or less commonly by unusual wind currents interacting with turbine parts.

2) Solar energy: Photovoltaic systems have the major demerit that the power output is reliant on direct sunlight, so about 10-25% is lost if a tracking system is not used since the cell will not be directly facing the sun at all times. Dust, clouds, and other things in the atmosphere also reduce the power output. Another main issue is the concentration of the production in the hours corresponding to main insolation, which doesn't usually match the peaks in demand in human activity cycles. Unless current societal patterns of consumption and electrical networks mutually adjust to this scenario, electricity still needs to be stored for later use or made up by other power sources, usually hydrocarbons.

3) Tidal energy: Tidal power can have effects on marine life. The rotating blades of a tidal turbine can kill the marine life species. Some fish may no longer utilise the area if threatened with a constant rotating or noise making object. If some mechanical fluids, such as lubricants, leak out, it can be very harmful to marine life species.

Among sources of renewable energy, tidal energy has confined availability of sites with sufficiently high tidal ranges or flow velocities thus constricting its total availability. It has been suffered from relatively high cost.

II. METHODS OF MITIGATION

In this section, we try to provide improvements and solutions to the problems pre-existing with the considered sources of renewable energy production.

1) Wind energy: As wind turbine design technologies improved, their power generating ability has increased from the 100KW – 200KW level to over 5 Megawatts per turbine. The wind speeds at which power generation occurs has also been enhanced so that turbines now produce power, even at low wind speeds of 5 km/h. Techniques are constantly being developed to progress the operational efficiencies of wind turbines. These developments should help grow the use of wind energy around the world. Some of these are discussed below:

a) New Bladeless Wind Turbine: Wind power has become an authentic source of energy over the past few decades as larger, more efficient turbine designs have formed ever-rising amounts of power. But still, though the industry saw a record \$99.5 billion global investment in 2014, turbine growth may be reaching its limits.

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Transportation of conservative wind turbines is rapidly demanding because of the mass of the components: individual blades and tower sections often need specialized trucks and straight, large roads. Today's wind turbines are also extremely summit heavy. Generators and gearboxes meeting on sustain towers 100 meters off the ground can weigh more than 100 tons. As the burden and height of turbines extend, the materials costs of wider, stronger sustain towers, as well as the cost of maintaining equipment housed so far from the ground, are cutting into the competence benefits of big turbines.

The alternative energy industry has continually tried to solve these issues to no avail. But the newest entry promises an entirely different type of wind turbine: a bladeless cylinder that oscillates or vibrates. Such turbines harness vortices, the gyratory motion of air or other fluids. When wind passes one of the cylindrical turbines, it shears off the leeward side of the container in a gyratory whirlpool or vortex. The whirlpool then exerts a force on the cylinder, causing it to vibrate. The kinetic energy of the oscillating container is converted to electricity through a linear generator similar to those used to bind wave energy.

The no blade technology is mostly inspired by the sailboat and is likely to amplify the efficiency of the current wind power conversion devices. The blades are replaced by a sail-shaped body while both hub and gearbox are removed. These devices are capable of overcoming the Betz' limit. An average wind turbine captures only 30 to 40%, while such a turbine is said to be 2.3 times more capable. Additionally, the cost is ordinary to be 45% less than a predictable turbine, mainly due to the fact that there are no blades, no hub, and no gearbox on the units.



Fig 2.1 Bladeless wind turbine

The no blade technology is different in other ways as well, most considerably being storage of energy. Most of the kinetic energy can be stored (via a hydraulic accumulator) or converted to electricity with a hydraulic motor and generator.

b) Airborne Turbines: Flying turbine concepts have appeared, at least in copyright papers, for many years and such ideas are currently generating amplified awareness. The designs are broadly classified as:

Systems supported by balloon buoyancy

Kites (lifting aerofoils)

Tethered autogyros.

Some systems mingle these features.

i) Floating wind turbines: It's a balloon that lifts a wind turbine. The majority wind turbine manufacturers are competing to make taller turbines to attach more powerful winds above 500 feet or 150 meters. But with the novel buoyant airborne turbine, we can go much higher. The airborne turbine can reach 2,000 feet or 600 meters. At this altitude, wind speeds are quicker and have five to eight time's superior power density. As a result, the turbine can produce more than twice the energy of a similarly rated tower-mounted turbine.

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ii) Kite Power Systems: Kite Power is a cost-efficient renewable energy solution with a low environmental footprint. The inflatable wing and the traction tether are made from strong but flexible lightweight materials. In contrast to usual wind turbines, this tensile structure is not obstructing the view. It is an ideal basis for a greatly mobile wind energy system. The heavy generator is situated at earth level, which facilitates servicing and also minimizes structural forces. The straight force transmission into the ground position removes the requirement for bending-resistant foundations, which is particularly interesting for deep-water offshore deployment. The technology uses a teleoperated airborne setup for the flight control of the kite, which can access altitudes extreme beyond the limit of ordinary wind turbines (200 m). Wind at these heights is stronger and steady which increases capacity factors of the system to about 60%. Conventional wind turbines presently achieve values of 20-35%.

Kites could be the future of wind energy. This unit has a number of advantages over traditional turbines. The kites are cheaper and easier to build and set up, all of the moving parts are at ground level for soft maintenance, and the scheme is much more durable and will last longer. The only part that's likely to break is the tether, which is a simple steel cable that's uncomplicated to replace. This type of power production might be the key to extra widespread adoption of wind power. Depending on the place, kite-based generators possibly will offer stable, constant power almost every day of the year, eliminating the biggest weakness of renewable energy. Conceivably in a few years, we'll all have kites soaring overhead, powering our homes and lives.



Fig 2.2 Buoyant Airborne Turbine

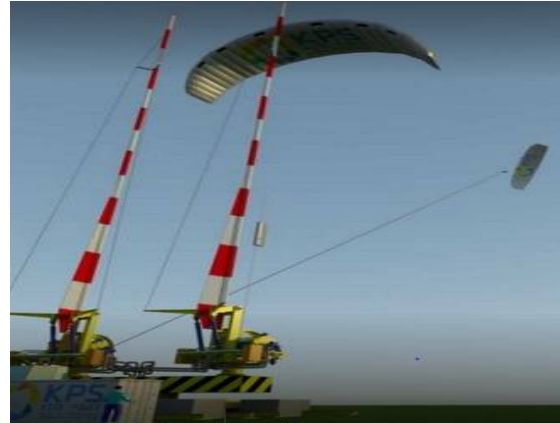


Fig 2.3 Kite Power System

c) Rope climbing robot inspects Wind Turbines: Wind Turbine blades are subject to damage from grit and other flying objects passed by the wind. The exposure to weather and wind also result in fatigue cracks. The turbine blades need to be inspected at regular intervals. Scrutiny by a technician would involve his hiking a 50 meter or higher mast, carrying examination equipment. This is hazardous and scheduled inspections often get deferred due to weather conditions or other reasons.

d) Laser Sensors to make Wind Turbines more efficient: Wind Turbines are already fitted with controls to move the turbine to face the wind direction for optimum power creation. These controls respond based on the wind speed and direction at the blade. A fibre-optic based laser device can be mounted on top of a wind turbine pole. This laser-based sensor is competent to sense wind speeds and direction at 100 meters' distance from the turbine that gives a 20-second early warning to the turbine controls of an impending wind shift. This early signal enables the blade controls to install in time for optimizing the blade angle and direction, ahead of the wind hitting the blades. This device is said to boost power output by some 10%.

2) Solar energy: Today's solar photovoltaic cells leave unused a major part of the energy existing in sunlight. They absorb a variety of wavelengths, typically from the blue to the near-infrared. When one of these photons strikes the semiconductor inside a solar cell, a single electron is excited to a higher energy level. When collected, these excited electrons can travel through a wire as current. But higher-energy blue and green photons deliver much more energy

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than required to excite an electron, and the extra energy is released as heat. Indeed, there's an acceptable limit to the efficiency that can be achieved in a solar cell designed with a single semiconductor. Given the distribution of photons in sunlight—each with its characteristic wavelength and energy—even an ideal solar cell could turn only 34% of the total energy into electricity.

One approach to solving the crisis of the efficiency limit is to stack up layers of different semiconductors, each absorbing different colours of sunlight. However, that approach is proving to be costly. A new method to breaking this barrier is the idea of singlet exciton fission.

The phenomenon—called singlet exciton fission—was first identified in the 1960s. The phenomenon has been observed in a variety of materials, all similar to a material called pentacene and all discovered—like pentacene—by chance. At the same time, while exciton fission has been confirmed within materials, it has never been achieved in a functioning solar cell.

The problem is that we can't rationally design materials and devices that take advantage of exciton fission until we understand the fundamental mechanism at work.

a) Achieving fission in a device: The first challenge is to build a solar cell that generates extra electrons. Devices built using pentacene combined with a fullerene, a hollow, all-carbon molecule that captures the exciton and releases electrons as current have shown satisfactory results.

To enhance the performance of such devices several structural improvements have been made e.g. addition of a polymer layer that protects the bottom interface of the pentacene layer, blocking the excitons but letting current flow through. In addition, a tuned mirror that enhances light absorption by the pentacene layer can be included.

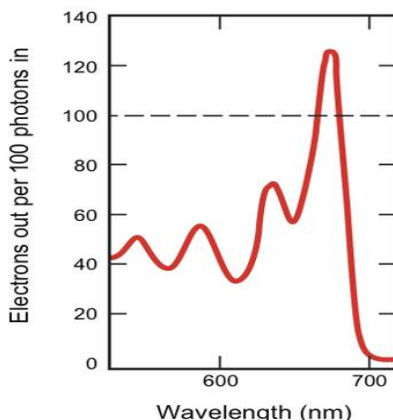


Fig 2.4 Electron output

b) Explaining the phenomenon: As per the classic theory, during exciton fission, an electron in an excited molecule exchange sits place with one in a neighbouring not-excited molecule. The electron from the excited molecule takes a portion of its energy with it, leaving the remnant behind, and in doing so forms two lower-energy excitons, each of which can release an electron.

If the electron-exchange mechanism is accurately predicted, then exciton fission would be most efficient when the molecules are physically packed close and electronically well-connected.

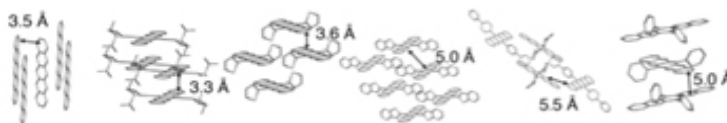


Fig 2.5 Packing in pentacene based molecules

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c) Design principles: Up to now, the results have already provided some useful design principles. For example, the most vital step is choosing a material with the right energy levels; if the energy ranking of the original exciton is more than twice the energy ranking of the two new excitons, then fission occurs spontaneously and rapidly.

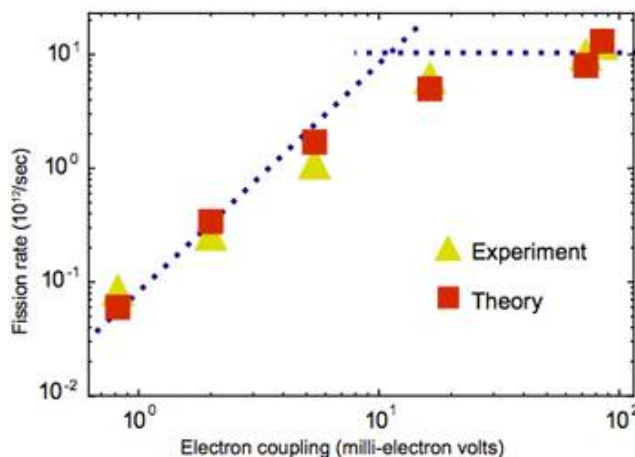


Fig 2.6 The effect of electronic coupling on exciton fission rate

This figure shows measured and calculated rates of exciton fission in thin films made of the six pentacene-based materials. As the electronic coupling of the material becomes stronger, the rate of exciton fission rises dramatically—until it finally comes to a level of saturation. At that point, the electrons are moving so rapidly that the molecules don't have time to make the adjustments needed to accommodate the exchange. Thus, the rate at which the molecules adapt limits the rate exciton fission.

d) Improving and applying the new device: To date, the energy conversion efficiency of assembled devices is less than 2%. However, this is a “proof of principle” system and further optimization will bring dramatic increases in efficiency.

Even so, such a new device won't be able to double the efficiency of solar cells because fission affects only the high-energy photons. Moreover, to get out twice as many electrons will require halving the energy per electron, and that effectively halves the voltage that the solar cell puts out.

As a result, these systems work not as stand-alone but rather as a coating on a conventional silicon solar cell. The low-energy photons (the infrared wavelengths) will be absorbed in the silicon, each generating one electron at the standard 0.6 volts. The coating will capture the high-energy photons (the blues and greens), create two low-energy excitons, and transfer the energy to the silicon, generating two electrons, also at 0.6 volts. The net result is that two photons can produce three electrons, all at the same energy.

3) Tidal energy: Tidal turbines draw on innovative technology and design to operate on both the inflow and outflow of water through them. The method of generation of renewable energy is particularly new, so there are not any advanced techniques for generation; in other words, we can say not a lot of work has been done in this field. The following techniques present solutions to the majority of the concerns existing in these systems:

a) Fouling and Tidal Turbine Efficiency: It will ensure that the structure becomes an ideal substrate for the growth of marine organisms when the biological events that happen when placing any structure in an area of high tidal currents and high biological productivity in the ocean. While turbines operating below the photic zone may be at a lesser risk; fouling by barnacles, algae and other organisms remain an issue for devices with long maintenance intervals. This can be mitigated by using coatings of different types over the turbine blades. Coating 1 is assumed to develop only thin slime over the 5 years' interval. Coating 2 will develop thick slime over the same period. In case of such an incident coating, 1 will be preferred over coating 2. Possible coatings include biocide paints and inert,

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low friction coatings. For an accurate estimation of the efficiency loss of the turbine due to such added roughness, the exact blade geometry should be used. Just as an approximation, we will here assume that the increase in drag resistance of the blade due to fouling is the same as in a bulk carrier (speed approx. 13-15 knots).

b) The need for new finance mechanisms: The new mechanism for finance emphasize on reducing installation and maintenance cost. The cost for tidal stream technologies is provided through government funds, or by technology developers themselves. Most of the countries are planning to promote a number of selected projects while other countries have started a more active policy on marine energies (e.g., feed-in tariffs and requests for proposals). But it is very hard to invest such a big amount to start a tidal power plant.

The need for new finance mechanisms is particularly relevant for the tidal stream technologies that have been tested at full scale but will require market pull mechanisms to deploy at scale. Possible ways of attracting investments could be by offering tax rewards for investors, by attracting end-users, or by feed-in tariffs that would make high-cost, pre-commercial installations more attractive. Furthermore, suitable mechanisms for risk sharing or lowering insurance risks could reduce the overall project costs.



Fig 2. 7 Reference pictures of “thin slime” (left) and “thick slime” (right)

c) Integrating the technology with other economic and societal functions: Most of the projects and work are particularly focused on the technology of the device itself and its direct infrastructure because the tidal range technology is relatively new. However, for larger schemes, a connection to other factors such as shipping, recreation, water defence and ecological impact could not only bring down installation costs (by better coordination of infrastructure) but also other types of costs and societal acceptance. For tidal stream technologies, there are a number of plans for hybrid systems combining floating offshore wind with tidal current technologies (e.g., a 500kW demonstration plant by MODEC in Japan). However, in most cases, tidal current technologies do not match well with offshore wind parks as the required strong tides increase the installation costs of the offshore wind parks.

d) Corrosion: For preventing the rotating blades from corrosion we use of corrosion-resistant materials such as stainless steels, high-nickel alloys, copper-nickel alloys, nickel-copper alloys and titanium can greatly reduce, or eliminate corrosion damage.

III. CONCLUSION

In this paper, we have discussed various techniques that could help to improve the sustainability and efficiency of renewable sources of energy in the present world and at the same time help to pave a path for future research into the field of reliability improvement of such sources.

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