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ON THE EFFICIENCY OF WIND GENERATORS AND SOLAR CELLS

Abstract: Basic principles of wind and solar cells generation are presented. Physical limitations and achieved results in efficiency for both principles are pointed out. Diapasons of prices of both type of energy were shown.

Key words: *wind generator, wind turbine, solar cells, efficiency of*

INTRODUCTION

Increasing demand for electrical energy as most convenient type of energy is forcing all countries to build more and more electric power capacities mainly using energents existing at their territories. Use of "domestic" energents is not connected only with its generally lower price but also with opportunity of employment of local people creating them chances for employment, existence and prosperity. Therefore many of existing electric power sources are not "surroundings friendly" while some of them are potentially extremely dangerous even for wider human community. Deep understanding that human society must stop to destroy soil we are living on, led to intensified investigations in the area of "alternative" sources of electrical energy which have not been attractive because of higher prices of their energy and because of not matured technology.

Today, although negotiations with local community are unavoidable, two "alternative" sources of electrical energy are widely accepted: wind and sunlight.

WIND GENERATION

Using of wind energy is well established through centuries[1], primarily for water pumping (draw-up of water), for windmills applications and finally for electricity generation.

Majority of nowadays wind-generators use three blade turbines with horizontal axis and driving generator located behind it, according to Fig. 1.

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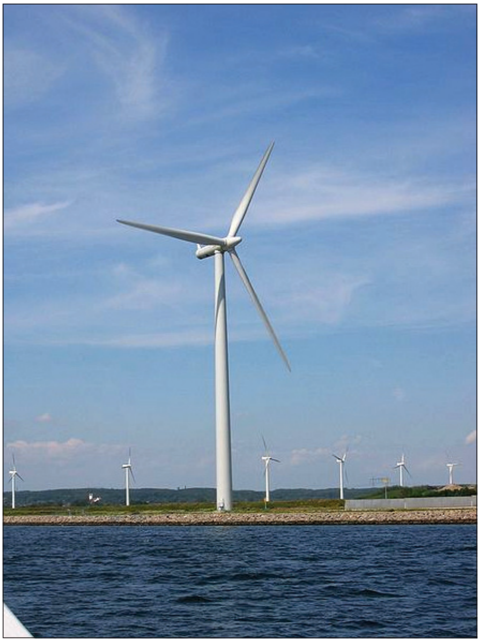

Fig. 1. Wind turbine with horizontal axis

Fig. 2. Wind generator crash

Although keeping “in-wind” position of a turbine could be much easier (without of additional unit) if turbine blades would be situated behind its tower (“downwind”), turbulences in the region behind the tower (in shadow of the tower) are causing dangerous vibrations of turbine blades (when passing the region) which could lead to its destruction, Fig. 2.

Therefore turbine is located upwind (in ahead of its tower) despite the fact that such location asks for automatic control system keeping turbine always in the wind direction (and causing additional losses in the wind power generation system). Other necessary components of wind generator are shown in Fig. 3. like “gear box” enabling appropriate speed of revolution of the generator and accordingly appropriate frequency of electrical output signal (50 c/s or 60 c/s).

Some wind generators are using solid-state power converters to interface to electric power system – the approach which offers possibility to use variable speed of revolutions and collecting more of energy.

In the described wind-generator concept, wind pressure on the turbine blades is representing efficient driving force. All other wind energy is passing through unused, in the areas (regions) in-between blades.

According to Betz´ law[2] wind turbine can get maximum 59% of the wind power. Peak efficiency of real turbines is always lower, determined by turbine construction and predefined wind speed. If wind speed differs of predefined one, turbine efficiency is lowering.

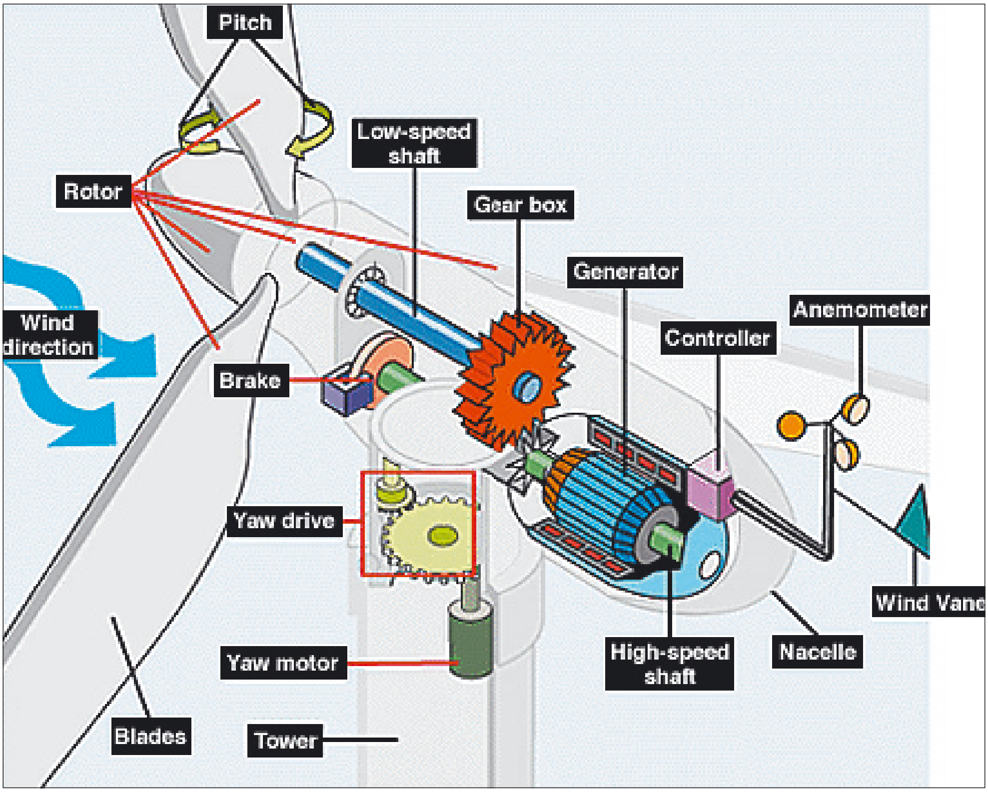

Fig. 3. Basic wind-generator components

Taking into account that typical efficiency of small generator is (93–97)% and losses in gear box (if it exists) are 2%, typical total efficiency of a turbine-generator unit, defined as "output on-load electric power" divided by "input wind power" could be about 35% (in the average 20%).

Today installed power of wind-generator are ranging to 7 MW[3] and with output voltage of 1 kV. A prototype of 10 MW was announced in 2010[4].

Prices of wind generated energy are becoming competitive with prices

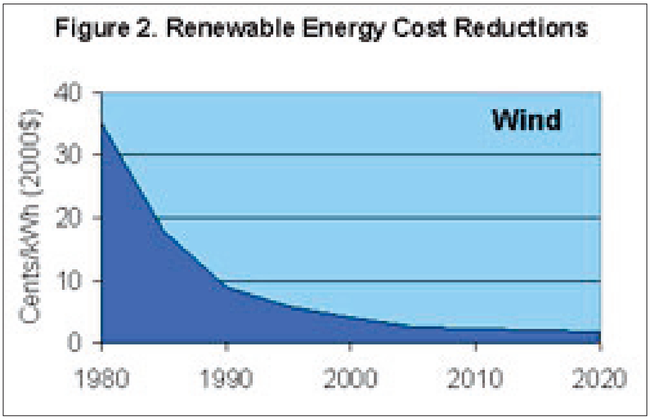

Fig. 4. Price of wind generated energy

of energy from conventional sources. Nowadays price of wind generated energy is about ten times lower then in 1980, figure 4.

To get an insight in physical dimensions and weights of “elegant looking wind generators” basic information on an 3 MW[5] power generator is given here:

Rotor:	diameter 90 m;
	swept area 6362 m^2;
Tower:	hub height 80 m and 105 m;
Weight:	nacelle 70 tons;
	rotor 41 tons;
	tower 160 tons – 235 tons, depending of the tower height.

SOLAR CELLS

Quite generally, devices converting energy of light into electrical energy are named photovoltaic cells. If the device is capturing energy of sunlight it is usually named as solar cell.

Most of solar cells are designed as p-n junction made of silicon. Silicon itself is element of fourth group (in Mendeleyev table) having fourteen electrons, four of them in valence band according to figure 5.

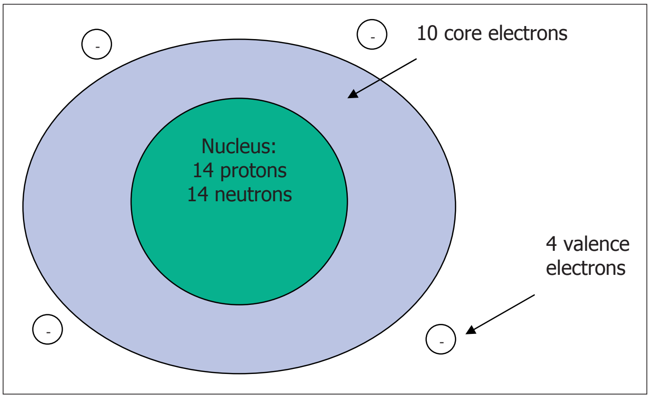

Fig. 5. Atom of silicon

N-type and p-type of silicon are formed by diffusion of elements of fifth and third group respectively, according to figures 6 and 7.

P-N junction is usually made by diffusion of n-type doppant in p-type wafer (or vice versa).

Because of different concentration of electrons in n-type and p-type material, electrons begun to move from region of higher concentration (n-type) to p-type region, leaving unneutralised positive and negative ions around the junction. This positive and negative electrical charge creates electrical field which prevents further diffusion of carriers across the junction, figure 8.

Formed p-n junction acts as a diode allowing, under external force, flow of electrons (current flow) in one direction only.

Therefore if photon hits a peace of silicon exciting an electron into conduction band, the electron could move through the silicon in only one direction.

Quite generally, if photon hits a piece of silicon:

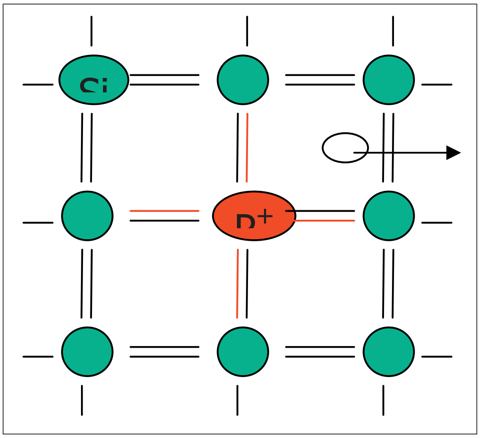

Fig. 6. N-type of silicon (diffusion of phosphorus in silicon)

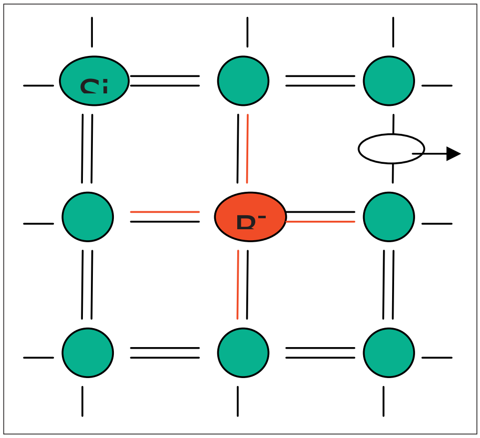

Fig. 7. P-type of silicon (diffusion of boron in silicon)

– it can be reflected of silicon surface, or
– it can pass straight through silicon, or
– it can be absorbed by the silicon.

Before been “excited” electrons were forming tight bonds (covalent bonds) with neighboring atoms, being unable to move further.

An electron can become “movable” only if get enough of energy to leave covalent bond and to reach “further” “conduction band”. The minimal amount of energy needed for this transition is known as “band gap energy”.

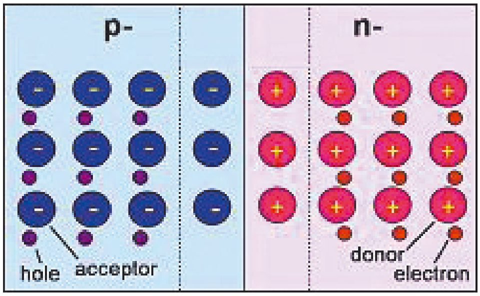

Fig. 8. P-N junction

If silicon absorbs photon with energy lower than “band-gap”energy, photon will simply pass through silicon heating it.

If silicon absorbs photon with high energy, photon will “excite” electron in crystal lattice moving it from “valence band” into “conduction band” but difference in energy between energy of the photon and silicon band-gap energy will not be converted in additional electrical energy but into heat.

Therefore great part of sunlight energy is lost. Coming into “conduction band” electron becomes free to move through semiconductor. Its former bond with neighboring atom now has one electron less (known as creation of a “hole”).

So each creation of one free electron is accompanied by creation of appropriate “hole”. Now electrons from covalent bonds of neighboring atoms are moving into the “hole”creating new “hole”on its former bond, wherefrom it follows that “hole”can move through lattice also. It means absorbed high energy photon is creating mobile electron-hole pair in the semiconductor material (silicon).

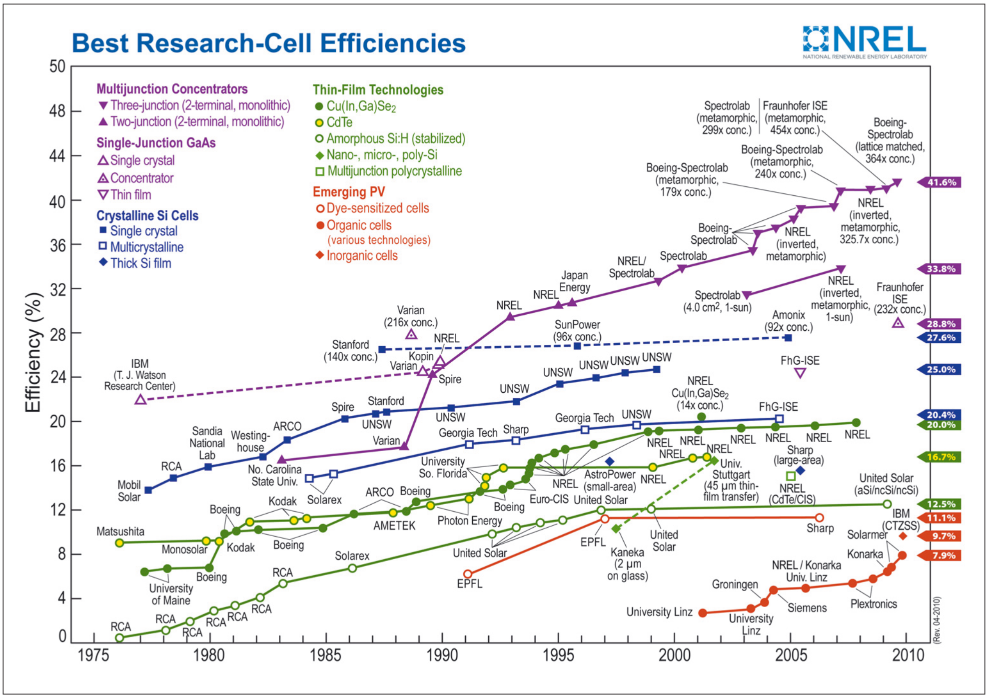

Fig. 9. Cell Efficiencies

Therefore solar cells made of multiple band gap absorber material could be more efficient in conversion of sunlight into electrical energy.

In attempt to improve conversion efficiency, many materials and technologies were tested or are under testing: multiple junction solar cells, thin film solar cells, crystalline silicon, concentrating photovoltaic…

An overview of research results on solar cells is given in figure 9.

One can see that the best efficiency (of 41,6%) has been reached for multijunction concentrators (three junctions, monolithic, two terminal).

Arrays of solar cells (paralleled series connections of solar cells to get wanted voltage and possibly current) are supplied as "solar panels" with predefined output peak power.

Output power of solar panel depends on illumination and therefore consumers are more interested in energy they can get from a solar panel during one day (24 hours). There is a strong rule that the average power of a solar panel is 20% of its peak power, so expected energy during a day can be calculated as 0.2 x peak power x 24 hours (par example: solar panel of 1 kW peak power will give 0.2 x 1 kWx 24 h = 4.8 kWh).

Solar cells are sources of DC energy and to connect them on electrical grid (which is AC), electronic inverters and appropriate batteries of accumulators should be used.

To calculate price per delivered kWh not only cell efficiency but also available irradiation and expected years of system life must be taken into account. Today most of solar panels are warranted for 25 years (with life expectancy of over 35 years). Their system efficiency is between 5% and 19% and prices per delivered kWh are in the range from 0.5 Euros (central Europe) to 0.25 Euros (regions of high solar irradiation), compared to prevailing retail prices of (0.04–0.5) Euros per kWh (from conventional electric power sources).

CONCLUSION

After initial period of testing and checking and technology improvement, non hydro renewable sources of electrical energy are becoming reality in many, especially high developed, countries.

Their life expectancy (of about 35 years) is comparable to the life expectancy of conventional sources of electrical energy and the cost of wind and solar electricity has come down by 80–90 percent over the past two decades tending to become competitive with prices of electrical energy from conventional sources over next decade[6].

Finally non hydro renewable sources of electrical energy seem to be friendlier to environment and human health then other sources of electrical energy.

LITERATURE

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