Electric Ion Wind Generator

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Abstract

A fundamentally new wind-induced electric generator without a rotor and a magnetic dynamo. The ion generator suggested is significantly cheaper, has high efficiency (67%) and can cover large areas, i.e., have a greater overall power production effect. It is based on the fact that the ions injected into the atmosphere are carried away by the ambient wind and create a potential difference of electric voltage, which produces an useable electric current.

Introduction. Wind Energy in World.

At present, 21st Century human life is very difficult without the presence of useful electricity. And, except for solar input, the Earth's energy resources are naturally limited. In addition, fossil fuels produce a large amount of carbon dioxide, which according to some scientists causes undesirable climate regime changes on Earth. Therefore, in recent years, much attention has been paid to all potentially renewable energy resources. In particular, wind energy (Fig. 1-2). Unfortunately, wind energy produced by the traditional mechanical method – using a rotor (propeller) and a dynamo - costs more (or, at least, about the same as) energy derived from exhumed fossil fuels. The main cost share in it is the expense of the tower, a large complex propeller and a dynamo. Mechanical parts wear out and have a relatively short operational life-span and maintenance comes also at a very high operational cost.

Herein, the author suggests a cheaper construction (for example, two suspended metal grids) that do not have moving mechanical parts.

Some countries are intensively developing wind power, in particular, in 2015, 42% of all electricity is produced by wind generators in Denmark; in 2014, Portugal ~27 %; in Nicaragua ~21%; in Spain ~20%; Ireland ~19%; in Germany ~18.8%; in the EU as a whole ~7.5 %. By 2014, 85 countries of the world used wind power on a commercial basis. By the end of 2015, wind power employed more than 1,000,000 people worldwide (including 500,000 in China and 138,000 in Germany).

Wind energy reserves are more than a hundred times higher than the estimated reserves of hydro-electric power of all rivers on the planet. The main part of the cost of wind energy is determined by the initial costs for the construction of wind power structures (the cost of 1 kW of installed wind power is ~$1000). Globally, the cost of electricity produced by wind turbines (not excluding the cost of wind installations) ranges from 2.6 cents/kWh to 4.8 cents/kWh and depends on the wind speed. For comparison, the cost of electricity produced at coal-fired power plants in the United States is 9-30 cents/kWh. The average cost of electricity in China is 13 cents/kWh.

In March 2006, the Earth Policy Institute (USA) reported that in two areas of the United States, the cost of wind power has become lower than the cost of traditional energy. The average price of electricity in the United States in 2007 rose to $0.0918 per kWh. According to Lawrence Berkeley National Laboratory (LBNL) [4] 12 new wind farms built in the United States in 2007 sold their electricity at prices ranging from $0.025 to $0.064 per kWh. However, by early-2020, in the USA, the total production of renewable electricity had exceed the production done by fossil fueling burning.

A 1 MW wind generator reduces annual emissions by 1,800 tons of CO_2, 9 tons of SO_2, and 4 tons of nitrogen oxides. |

The US wind power industry is the fastest growing renewable energy industry in the country. At the end of 2015, the US had 74.5 GW of installed capacity, second only to China. In 2015, 8.6 GW of new capacity was added. The US wind power industry generates approximately 5% of the country's electricity.

Current wind power is the USA is generated by the air flow through wind turbines to mechanically power generators for electric power. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, consumes no water, and uses little land. The net effects on the environment are far less problematic than those of nonrenewable power sources (Fig. 1-2).

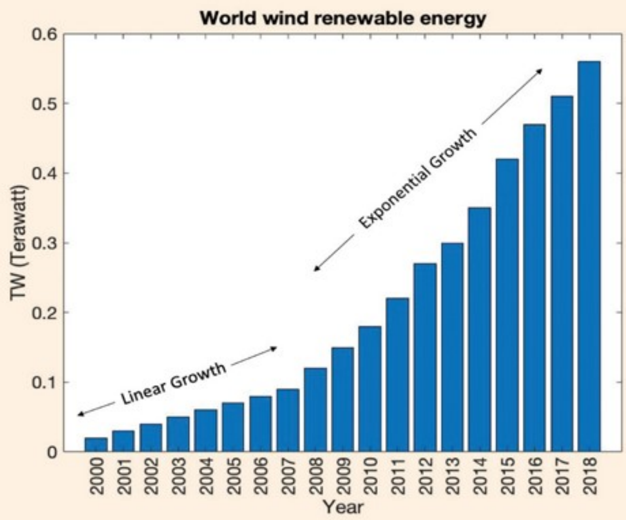

FIGURE 1. **Growth of the Global Power Capacity of Wind Energy Since the Year 2000**

At the beginning, growth was linear, but now it has taken off and wind energy capacity increases exponentially.

(Sources: IRENA, BWE, and GWEC)

Fig. 2. Typical rotor wind generator farm, present time.

Device description

The schematic diagram of the proposed device is shown in Fig. 3. The Device consists of two conductive (for example, metal) grids 2-3 installed perpendicular to the prevailing wind 1 in the given area. The grids are connected to a capacitor 4 that creates a braking electric field between them. Ion injectors 5 are attached to the grid 2, connected to each other by wires, but isolated from the grids 2 – 3. The ion injectors are connected to the electron injectors 6 located on the grid 3, but isolated from it. A current consumer 7 is included in the connection of injectors 5-6.

The device works as follows. A charged capacitor 4 (or other device) creates a braking electric field between the plates 2 – 3. The ion source 4 injects ions into the wind stream 1. If an ion takes charge from an air molecule, it is replaced by an air molecule ion that has the same sign as the previous ion. Ions attracted to the grid 2 and repelled by the grid 3 are moved to the grid 3 by the kinetic energy of the flow. But they inhibit the air flow 1 between the plates 2 - 3. The kinetic energy of the wind is converted into pressure, which moves the ions in turn is converted into the potential difference between charges. The electron injector 6 closes the electrical circuit, neutralizing the excess of ions through the consumer 7. The Neutralized ions flow out of the grid 3.

Calculations show that the energy spent on charge separation (positive ions and negative electrons) is many times less than the kinetic energy of the wind flow. Previously, the author has shown [1] that based on this idea, it is possible to create powerful ion electric generators that convert the energy of gas or plasma pressure into electricity.

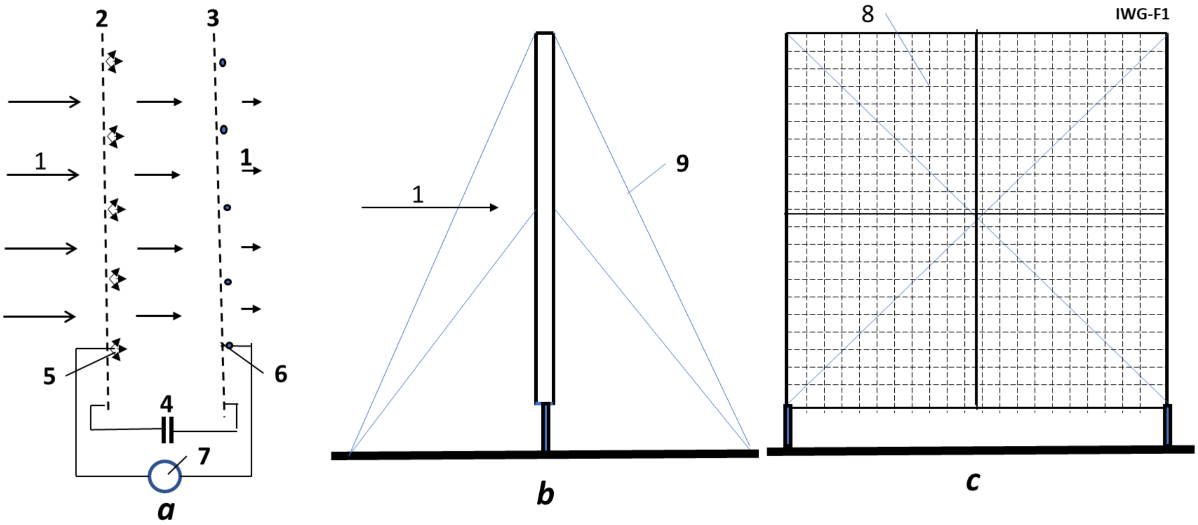

Fig. 3. Schematic diagram of an ion wind electric generator. *Notation*: (***a***) - (schematic diagram): 1- wind, 2 – 3 – conducting grids, 4 - charged capacitor, 5 – ion injector, 6 - electron injector, 7 - energy consumer. (**b**) - side view, (***c***) - front view. 8 - conducting grids, 9 - braces.

In addition to the installation shown in Fig. 3, simpler installations are possible. They are shown in Fig. 4-5, and consisting of a Central electrode and a remote wire. They may be less effective, but they cover a large area.

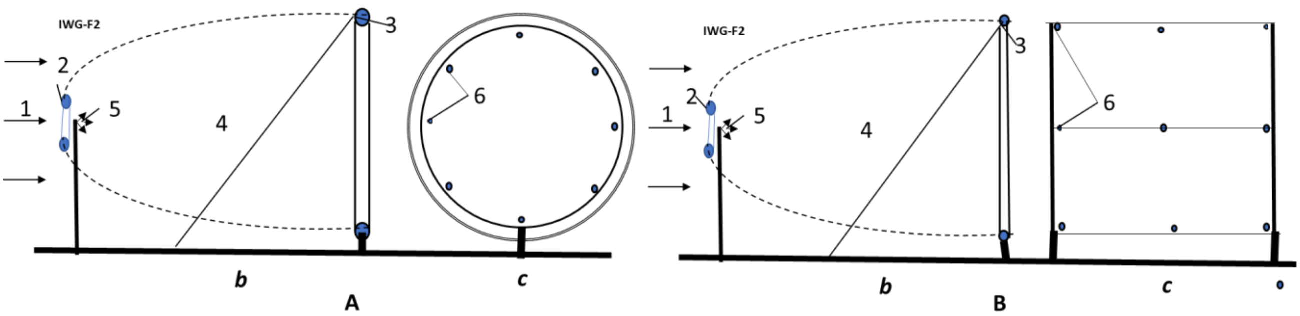

Fig. 4. Creating an electrostatic field. *Notation*: **A** – using two conductive rings, **B** - (right) - using a ring and horizontal wires. (*b* - side view, *c* - front view): 1 - wind, 2 - first ring, 3 - second ring, 4 - electrostatic field, 5 - ion injector, 6 - electronic injectors.

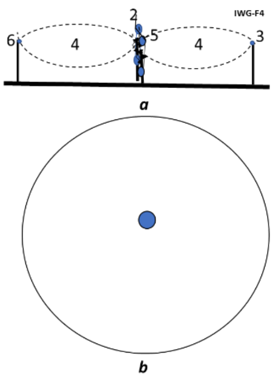

Fig. 5. Creating a central electrostatic field using a central electrode and an annular wire to dispose of wind from any direction. Designations: 2 – first ring, 3 - second ring, 4 - electrostatic field, 5 - ion injector, 6 - electronic injectors.

Advantages of the proposed method in comparison with the existing best rotary (propeller) wind installations:

1. Efficiency increases from 0.5 to 0.67 - the maximum possible.
2. The installation can work on *any* wind speed. Rotary installations are limited to safe speeds of 3-4 m/s.
3. The upper limit of wind velocity is also not restricted. For rotary wind turbines, the upper limit is limited by the strength of the rotor and storm durability is always a strong operational concern.
4. Low cost of installations (no tower, complex propeller, dynamo, transformer).
5. Produces high-voltage direct current at once, convenient for transmitting long distances with low losses (less than 5%).
6. The long-term durability of the sturdy installation and minor maintenance costs (no mechanical parts).
7. The service life, without major repairs, can reach more than 20 years (the service life of ion rocket engines reaches 200,000 hours).
8. Easy to move the installation to a new location.

Theory of wind

Power of a wind energy N [Watt, Joule/sec]

$$N = 0.5\eta\rho A V^3 \quad [\text{W}] \qquad (1)$$

The rotor coefficient of efficiency, η, equals 0.15 - 0.35 for low speed rotors (ratio of blade tip speed to wind speed equals $\lambda \approx 1$); $\eta = 0.35 - 0.5$ for high speed rotors ($\lambda = 5 - 7$). The Darrius rotor has $\eta = 0.35 - 0.4$. The propeller rotor has $\eta = 0.45 - 0.50$. The theoretical maximum of any wind installation equals $\eta = 0.67$.

The energy produced in one year amount (1 year $\approx 30.2\times10^6$ work sec) [J]

$$E = 3600\times24\times350 \approx 30\times10^6 N \quad [\text{J}]. \qquad (2)$$

Wind speed increases with altitude as follows

$$V = (H/H_o)^{\alpha} V_o\,, \qquad (3)$$

where $\alpha = 0.1 - 0.25$ exponent coefficient depends from surface roughness. When the surface is water, $\alpha = 0.1$; when surface is shrubs and woodlands $\alpha = 0.25$.

Power increases with altitude as the cube of wind speed

$$N = (H/H_o)^{3\alpha} N_o, \qquad (4)$$

where N_o is power at H_o, H – height, m.

The drag of the rotor equals

$$D_r = N/V \quad [\text{N}] \qquad (5)$$

Theory of wind electric generator. Computation and Estimation.

1. Ion and electron speed.

Ion mobility. The ion speed onto the mixed gas (air) jet may be computed by equation:

$$j_s = qn_- b_- E + qD_-(dn_-/dx)\,, \qquad (6)$$

where j_s is density of electric current about jet, A/m^2; $q = 1.6\times10^{-19}$ C is charge of single electron, C; n_- is density of injected negative charges in 1 m^3; b_- is charge mobility of negative charges, m^2/sV; E is electric intensity, V/m; D_- is diffusion coefficient of charges; dn_-/dx is gradient of charges. For our estimation we put $dn_-/dx = 0$. In this case

$$j_s = qn_- b_- E\,, \quad Q = qn\,, \quad v = bE\,, \quad j_s = Qv\,, \qquad (7)$$

where Q is density of the negative charge in 1 m^3; v is speed of the negative charges about jet, m/s.

The air negative charge mobility for normal pressure and temperature $T = 20^{o}$C is:

In dry air $b_- = 1.9\times10^{-4}$ m^2/sV, in humid air $b_- = 2.1\times10^{-4}$ m^2/sV. (8)

In Table 1 is given the ion mobility of different atmospheric gases for pressure 700 mm Hg and for T = 18ºC.

Table 1. Ions mobility of different gases for pressure 700 mm Hg and for T = 18 ºC.

Gas	Ion mobility 10^{-4} m²/sV, b_+, b_-	Gas	Ion mobility 10^{-4} m²/sV, b_+, b_-	Gas	Ion mobility 10^{-4} m²/sV, b_+, b_-
Hydrogen	5.91 8.26	Nitrogen	1.27 1.82	Chloride	0.65 0.51
Oxygen	1.29 1.81	CO_2	1.10 1.14		

Source [1] p.62.

In diapason of pressure from 13 to 6×10^6 Pa the mobility follows the Law bp = const, where p is air pressure. When air density decreases, the charge mobility increases. The mobility strength depends upon the purity of gas. The ion gas mobility may be recalculated in other gas pressure p and temperature T by equation:

$$b = b_0 \frac{T p_0}{T_0 p}, \qquad (9)$$

where lower index "$_o$" mean the initial (known) geographical point. At the Earth surface H_o = 0 km, T_0 = 288 K, p = 1 atm; at altitude H = 10 km, T_0 = 223 K, p = 0.261 atm;

For normal air density the electric intensity must be less than 3 MV (E < 3 MV/m) and depends from pressure.

Electron mobility. The ratio $E/p \approx$ constant. Conductivity σ of gas depends upon density of charges particles n and their mobility b, for example:

$$\sigma = neb, \quad \lambda = 1/n\sigma, \qquad (10)$$

where b is mobility of the electron, λ is a free path of electron.

Electron mobility depends from ratio E/n . This ratio is given in Table 2.

Table 2. Electron mobility b_e in gas vs E/n

Gas	***E/n*** $\times10^{-17}$ 0.03 V·cm²	***E/n*** $\times10^{-17}$ 1 V·cm²	***E/n*** $\times10^{-17}$ 100 V·cm²	Gas	***E/n*** $\times10^{-17}$ 0.03 V·cm²	***E/n*** $\times10^{-17}$ 1 V·cm²	***E/n*** $\times10^{-17}$ 100 V·cm²
N_2	13600	670	370	He	8700	930	1030
O_2	32000	1150	590	Ne	16000	1400	960
CO_2	670	780	480	Ar	14800	410	270
H_2	5700	700	470	Xe	1980	-	240

Source: Physics Encyclopedia http://www.femto.com.ua/articles/part_2/2926.html

The electrons may connect to the neutral molecules and produce the negative ions (for example, affinity of electron to N equals 0.2 – 0.69, O_2 equals 0.3 - 0.87 eV, to H_2O equals 0.9 eV [4] p.423-4). That way the computation of the mobility of a gas containing electrons and ions is a complex problem. Usually the computations are made for all electrons converted to ions.

The maximal electric intensity in air at the Earth surface is E_m = 3 MV/m. If atmospheric pressure changes the E_m also changes by law E_m/p = constant.

Example 4. If $E = 10^5$ V/m, then v = 20 m/s in Earth surface conditions.

Ionization energy.

Energy is needed for ionization at Fig.6.

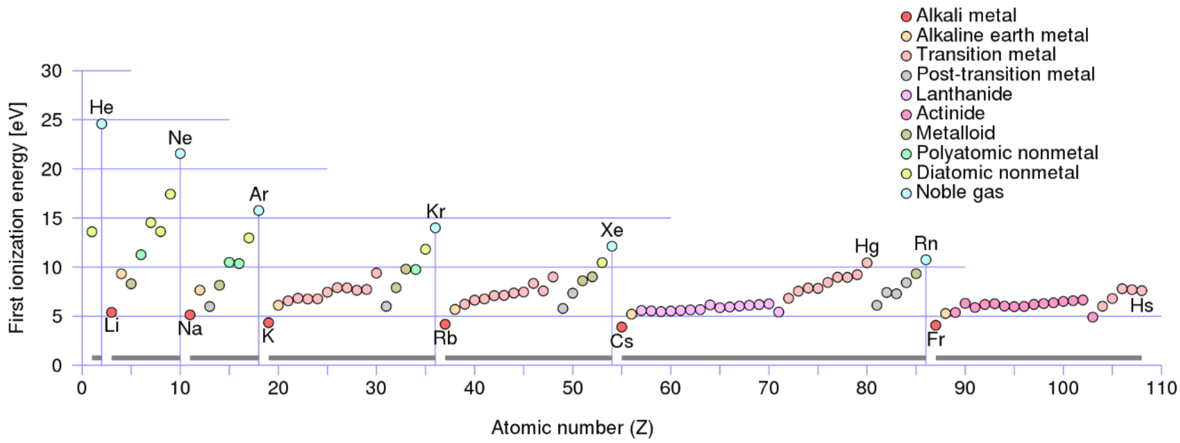

Fig.6. Energy is needed for ionization [5].

Example. Evaluation.

Let's show by example what data can be obtained from the proposed ion wind generator. Let's assume that we have constructed a metal double grid *S* = 100×100 m with a distance between the grids of *l* = 5 m. The grids were installed vertically and perpendicular to the prevailing wind direction in the given Earth-surface area (Fig. 3 b, c). Let the wind have a speed of *v* = 10 m/s.

Let's estimate, what power (voltage and current) we can get from such an ion generator and what brake pressure we should use. Let's assume that positive charged ions are used (as in rocket ion engines). Then the first grid should be charged negatively, and the second – positively. The electric field intensity between the grids is constant. The wind will tend to attract the ions to the second grid, and the electric field, on the contrary, will prevent this.

Installation area is $A = 100\text{x}100\ \text{m}^2 = 10^4\ \text{m}^2$, having the distance between nets *l* = 5 m.
Wind speed *v* = 10 m/s.

The maximum power, getting from the wind in area 1 m^2 at maximum efficiency $\eta_m = 0.67$, is

$$N_1 = N/A = 0.5\,\eta_m\,\rho\, v^3 = 0.5\cdot 0.67\cdot 1.22\cdot 10^3 = 409 \quad [\text{W/m}^2], \qquad (11)$$

Where N_1 is an electric power of area 1 m^2; *N* is power of full wind installation, W; $\rho = 1.22$ kg/m^3 is air density.

From limit of speed ion v_i, we have

$$v_i =< v \ \text{ or } \ bE < v, \quad \text{where } \ E = U/l\,. \qquad (12)$$

Here v_i – ion speed, m/s; *v* – wind speed, m/s; $b_+ = 1.9\cdot10^{-4}$ mobility of positive air ion, m^2/s*V* (*V* is voltage); *E* – electric intensity, V/m; *U* – voltage, V; *l* – distance between nets, m.
Or

$$U =< vl/b = 10\cdot 5/(1.9\cdot 10^{-4}) = 263\ \text{kV}\,. \qquad (13)$$

That means: the currency from 1 m^2 is

$$i_1 = N_1/U = 409/263\cdot 10^3 = 1.86\cdot 10^{-3} \quad \text{A/m}^2. \qquad (14)$$

Let us estimate the loss for ionizing the currency equal i_1. For getting the ions we can us any element, by better to use the elements having small energy for living the atom. For example: lithium, natrium, kalium, etc.: Li-7, Na-23, K-40, Rb—85, Cs-133, etc., having electron energy E_e= 5 eV, Fig.6.

Expenditure of ions from 1 m^2 is

$$\mathbf{N}_1 = i_1/e = 1.86\cdot 10^{-3}/1.6\cdot 10^{-19} = 1.16\cdot 10^{16} \quad 1/\text{m}^2\text{s}\,. \qquad (15)$$

Let us take ion of Li-7 (*n* = 7). Expenditure of ions mass from 1 m^2 is

$$M_1 = \mathbf{N}_1 n m_p = 1.16\cdot 10^{16} 7\cdot 1.67\cdot 10^{-27} = 1.36\cdot 10^{-10} \quad \text{kg/m}^2\text{s}\,, \qquad (16)$$

Expenditure of ions mass from full area $S = 10^4$ m^2 is

$M = M_1S = 1.36{\cdot}10^{-10}10^4 = 1.36{\cdot}10^{-6}$ kg/s $= 1.36{\cdot}10^{-6}\ {\cdot}8.46{\cdot}10^5 = 1.15$ kg/day. (17)

Where 1 day have $8.46{\cdot}10^5$ sec.

Expenditure of ions power from area $S = 1$ m^2 for ionization $\varepsilon = 5$ eV is

$$p_i = N_1\varepsilon e = 1.16{\cdot}10^{16}5{\cdot}1.6{\cdot}10^{-19} = 9.3{\cdot}10^{-3}\ \ \text{W/m}^2. \qquad (18)$$

That is very small value with comparison 409 W/m^2. We neglect it. We can take the efficiency of installation equal maximum, $\eta_m = 0.67$.

Summary: Calculi Wind Installation $S = 100$x100 m^2 for wind speed $v = 10$ m/s produce power $P = 409{\cdot}10^4 = 4.09$ MW, voltage 263 kV and electric currency $I = i_1S = 1.86{\cdot}10^{-3}\ 10^4 = 18.6$ Ampere.

Air drag of wind installation

Air drag for wind speed $v = 10$ m/s is

$$D = P/v = 4{,}090{,}000/10 = 0.409 \text{ MN} \approx 41 \text{ tons}. \qquad (19)$$

Note. The first net (grid) may has one power ion injector located at distance 0.5l from the second net (figs. 4 – 5) or some ion injectors may locate 0.5l or less. The electron injectors must be located on the frame of the second net.

The theory of ions injectors is well developed and widely used [2 – 4]. The electron injectors are known long ago, very simple. They are sharp needles in electric field.

Discussion

Existing wind farms have expensive structures (towers, rotors with automatic rotating blades. Magnetic dynamos, transformers, maintenance). Although they do not require fuel, the resulting energy is in most cases more expensive than energy from fossil fuels.

The proposed installation is simple, cheap, has a significantly higher (theoretically highest) efficiency (0.67, and the rotor is 0.5, i.e. 34% more) and can be used both on the ground and at high altitudes. In addition, the unit produces high-voltage direct current convenient for long-distance transmission with less loss.

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