Electrostatic Generator and Electronic Transformer

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Abstract

Transmission of high voltage by direct currency (DC) over long distance has big advantages in comparison with the current transmission by alternative current (AC). But about one hundred years ago generating electricity by the magnetic method was easy and development led to a system centered on AC. Now AC is the dominant method. That is only a result of the quirks of electricity's historical development.

In present time it is possible to research and develop (R&D) high voltage electrostatic generators and inverters of high voltage DC in low voltage DC and in AC and using the old AC lines and devices.

Author offers a cheap high voltage electrostatic generator and transformer of high voltage DC to low voltage DC and DC in AC (any frequency and phases) and back. That may be adopted gradually and it will give significantly savings of electricity and energy.

Introduction

Electric Generator.

In electricity generation, an electric generator is a device that converts mechanical energy to electrical energy. A generator forces electric current to flow through an external circuit. The source of mechanical energy may be a reciprocating or turbine steam engine, water falling through a turbine or waterwheel, an internal combustion engine, a wind turbine, a hand crank, compressed air, or any other source of mechanical energy. Generators provide nearly all of the power for electric power grids.

The reverse conversion of electrical energy into mechanical energy is done by an electric motor, and motors and generators have many similarities. Many motors can be mechanically driven to generate electricity and frequently make acceptable generators.

Electrostatic generator,

is a mechanical device that produces *static electricity*, or electricity at high voltage and low continuous current. The knowledge of static electricity dates back to the earliest civilizations, but for millennia it remained merely an interesting and mystifying phenomenon, without a theory to explain its behavior and often confused with magnetism. By the end of the 17th Century, researchers had developed practical means of generating electricity by friction, but the development of electrostatic machines did not begin in earnest until the 18th century, when they became fundamental instruments in the studies about the new science of electricity. Electrostatic generators operate by using manual (or other) power to transform mechanical work into electric energy. Electrostatic generators develop electrostatic charges of opposite signs rendered to two conductors, using only electric forces, and work by using moving plates, drums, or belts to carry electric charge to a high potential electrode. The charge is generated by one of two methods: either the triboelectric effect (friction) or electrostatic induction.

Electric-power transmission

is the bulk transfer of electrical energy, from generating power plants to electrical substations located near demand centers. This is distinct from the local wiring between high-voltage substations and customers, which is typically referred to as electric power distribution. Transmission lines, when interconnected with each other, become transmission networks. The combined transmission and distribution network is known as the "power grid" in the United States, or just "the grid". In the United Kingdom, the network is known as the "National Grid".

A wide area synchronous grid, also known as an "interconnection" in North America, directly connects a large number of generators delivering AC power with the same relative phase, to a large number of consumers. For example, there are three major interconnections in North America (the Western Interconnection, the Eastern Interconnection and the Electric Reliability Council of Texas (ERCOT) grid), and one large grid for most of continental Europe.

The electric transmission may be **overhead** and underground. High-voltage overhead conductors are not covered by insulation. The conductor material is nearly always an aluminum alloy, made into several strands and possibly reinforced with steel strands.

Today, transmission-level voltages are usually considered to be 110 kV and above. Lower voltages such as 66 kV and 33 kV are usually considered subtransmission voltages but are occasionally used on long lines with light loads. Voltages less than 33 kV are usually used for distribution. Voltages above 230 kV are considered extra high voltage and require different designs compared to equipment used at lower voltages.

Electric power can also be transmitted by underground power cables instead of overhead power lines. Underground cables take up less right-of-way than overhead lines, have lower visibility, and are less affected by bad weather. However, costs of insulated cable and excavation are much higher than overhead construction.

Engineers design transmission networks to transport the energy as efficiently as feasible, while at the same time taking into account economic factors, network safety and redundancy. These networks use components such as power lines, cables, circuit breakers, switches and transformers.

Transmission and distribution losses in the USA were estimated at 6.6% in 1997 and 6.5% in 2007.

As of 1980, the longest cost-effective distance for direct-current transmission was determined to be 7,000 km (4,300 mi). For alternating current it was 4,000 km (2,500 mi), though all transmission lines in use today are substantially shorter than this.

In any alternating current transmission line, the inductance and capacitance of the conductors can be significant. Currents that flow solely in 'reaction' to these properties of the circuit, (which together with the resistance define the impedance) constitute reactive power flow, which transmits no 'real' power to the load.

These reactive currents however are **very** real and cause extra heating losses in the transmission circuit. The ratio of 'real' power (transmitted to the load) to 'apparent' power (sum of 'real' and 'reactive') is the power factor. As reactive current increases, the reactive power increases and the power factor decreases. For transmission systems with low power factor, losses are higher than for systems with high power factor. Utilities add capacitor banks, reactors and other components (such as phase-shifting transformers; static VAR compensators; physical transposition of the phase conductors; and flexible AC transmission systems, FACTS) throughout the system to compensate for the reactive power flow and reduce the losses in power transmission and stabilize system voltages. These measures are collectively called 'reactive support.

High-voltage direct current.

High-voltage direct current (HVDC) is used to transmit large amounts of power over long distances or for interconnections between asynchronous grids. When electrical energy is to be transmitted over very long distances, the power lost in AC transmission becomes appreciable and it is less expensive to use direct current instead of alternating current. For a very long transmission line, these lower losses (and reduced construction cost of a DC line) can offset the additional cost of the required converter stations at each end.

HVDC is also used for submarine cables because over about 30 kilometres (19 mi) lengths AC cannot be supplied. In these cases special high voltage cables for DC are used. Submarine HVDC systems are often used to connect the electricity grids of islands, for example, between Great Britain and mainland Europe, between Great Britain and Ireland, between Tasmania and the Australian mainland, and between the North and South Islands of New Zealand. Submarine connections up to 600 kilometres (370 mi) in length are presently in use.

HVDC links can be used to control problems in the grid with AC electricity flow. The power transmitted by an AC line increases as the phase angle between source end voltage and destination ends increases, but too large a phase angle will allow the systems at either end of the line to fall out of step. Since the power flow in a DC link is controlled independently of the phases of the AC networks at either end of the link, this phase angle limit does not exist, and a DC link is always able to transfer its full rated power. A DC link therefore stabilizes the AC grid at either end, since power flow and phase angle can then be controlled independently.

As an example, to adjust the flow of AC power on a hypothetical line between Seattle and Boston would require adjustment of the relative phase of the two regional electrical grids. This is an everyday occurrence in AC systems, but one that can become disrupted when AC system components fail and place unexpected loads on the remaining working grid system. With an HVDC line instead, such an interconnection would: (1) Convert AC in Seattle into HVDC. (2) Use HVDC for the three thousand miles of cross-country transmission. Then (3) convert the HVDC to locally synchronized AC in Boston, (and possibly in other cooperating cities along the transmission route). Such a system could be less prone to failure if parts of it were suddenly shut down. One example of a long DC transmission line is the Pacific DC Intertie located in the Western United States.

The cost of high voltage electricity transmission (as opposed to the costs of electric power distribution) is comparatively low, compared to all other costs arising in a consumer's electricity bill. In the UK transmission costs are about 0.2p/kWh compared to a delivered domestic price of around 10 p/kWh.

Research evaluates the level of capital expenditure in the electric power T&D equipment market will be worth $128.9bn in 2011.

Advantages of HVDC over AC transmission.

The most common reason for choosing HVDC over AC transmission is that HVDC is more economic than AC for transmitting large amounts of power point-to-point over long distances. A long distance, high power HVDC transmission scheme generally has lower capital costs and lower losses than an AC transmission link.

Even though HVDC conversion equipment at the terminal stations is costly, overall savings in capital cost may arise because of significantly reduced transmission line costs over long distance routes. HVDC needs fewer conductors than an AC line, as there is no need to support three phases. Also, larger conductors can be used since HVDC does not suffer from the skin effect. These factors can lead to large reductions in transmission line cost for a long distance HVDC scheme.

Depending on voltage level and construction details, HVDC transmission losses are quoted as about 3.5% per 1,000 km, which is less than typical losses in an AC transmission system. HVDC transmission may also be selected because of other technical benefits that it provides for the power system. HVDC schemes can transfer power between separate AC networks. HVDC powerflow between separate AC systems can be automatically controlled to provide support for either network during transient conditions, but without the risk that a major power system collapse in one network will lead to a collapse in the second.

The combined economic and technical benefits of HVDC transmission can make it a suitable choice for connecting energy sources that are located far away from the main load centers.

Specific applications where HVDC transmission technology provides benefits include:

Undersea cables transmission schemes (e.g., 250 km Baltic Cable between Sweden and Germany, the 580 km NorNed cable between Norway and the Netherlands, and 290 km Basslink between the Australian mainland and Tasmania).

Endpoint-to-endpoint long-haul bulk power transmission without intermediate 'taps', usually to connect a remote generating plant to the main grid, for example the Nelson River DC Transmission System in Canada.

Increasing the capacity of an existing power grid in situations where additional wires are difficult or expensive to install.

Power transmission and stabilization between unsynchronised AC networks, with the extreme example being an ability to transfer power between countries that use AC at different frequencies. Since such transfer can occur in either direction, it increases the stability of both networks by allowing them to draw on each other in emergencies and failures.

Stabilizing a predominantly AC power-grid, without increasing fault levels (prospective short circuit current).

HVDC Converter.

At the heart of an HVDC converter station, the equipment which performs the conversion between AC and DC is referred to as the *converter*. Almost all HVDC converters are inherently capable of converting from AC to DC (*rectification*) and from DC to AC (*inversion*), although in many HVDC systems, the system as a whole is optimised for power flow in only one direction. Irrespective of how the converter itself is designed, the station which is operating (at a given time) with power flow from AC to DC is referred to as the *rectifier* and the station which is operating with power flow from DC to AC is referred to as the *inverter*.

Early HVDC systems used electromechanical conversion (the Thury system) but all HVDC systems built since the 1940s have used electronic (static) converters. Electronic converters for HVDC are divided into two main categories: Line-commutated converters (LCC), Voltage-sourced converters, or current-source converters.

A magnetic transformer

is an electrical device that transfers energy between two or more circuits through electromagnetic induction. A varying current in the transformer's primary winding creates a varying magnetic flux in the core and a varying magnetic field impinging on the secondary winding. This varying magnetic field at the secondary induces a varying electromotive force (emf) or voltage in the secondary winding. Making use of Faraday's Law in conjunction with high magnetic permeability core properties, transformers can thus be designed to efficiently change AC voltages from one voltage level to another within power networks.

Transformers range in size from RF transformers a small cm^3 fraction in volume to units interconnecting the power grid weighing hundreds of tons. A wide range of transformer designs are used in electronic and electric power applications. Since the invention in 1885 of the first constant potential transformer, transformers have become essential for the AC transmission, distribution, and utilization of electrical energy.

Costs of high voltage DC transmission.

Generally, providers of HVDC systems, such as **Alstom**, Siemens and ABB, do not specify cost details of particular projects. It may be considered a commercial matter between the provider and the client.

Costs vary widely depending on the specifics of the project (such as power rating, circuit length, overhead vs. cabled route, land costs, and AC network improvements required at either terminal). A detailed comparison of DC vs. AC transmission costs may be required in situations where there is no clear technical advantage to DC alone, and economical reasoning drives the selection.

However, some practitioners have provided some information:

For an 8 GW 40 km link laid under the English Channel, the following are approximate primary equipment costs for a 2000 MW 500 kV bipolar conventional HVDC link (exclude way-leaving, on-shore reinforcement works, consenting, engineering, insurance, etc.)

Converter stations ~£110M (~€120M or $173.7M)

Subsea cable + installation ~£1M/km (~€1.2M or $6M/km)

So for an 8 GW capacity between England and France in four links, little is left over from £750 M for the installed works. Add another £200–300M for the other works depending on additional onshore works required.

An April 2010 announcement for a 2,000 MW, 64 km line between Spain and France is estimated at €700 million. This includes the cost of a tunnel through the Pyrenees.

Electric generator

Current electric grid needs a great deal of electricity which can be gotten either from a nuclear reactor, steam turbine or from connection of the conventional turbojet engine with an electric generator (gas turbine). Let us consider the last possibility.

When industry needs electricity, most electric engineers offer the conventional way: take the usual magnetic electric generator and connect it to the turbojet or other (for example, piston) engine.

Let us analyze the limiting possibilities of different versions.

Magnetic electric generator.

Magnetic electric generator was first produced about century ago and has been very well studied. The ratio of power/mass of magmatic generator for 1 m³ may be estimated by equation:

$$A=\frac{B^2}{2\mu_0}, \quad P=A\nu, \quad M=\gamma, \quad \frac{P}{M}=c\frac{B^2\nu}{2\mu_0\gamma}, \qquad (1)$$

Here A is density of energy into 1 m³ of magnetic material J/m³; B is maximal magnetic intensity, T; μ_0 =

$4\pi 10^{-7}$ is magnetic permeability (magnetic constant), N/A²; P is power, W; υ is electric frequency, 1/s (υ = 50 ÷ 400 1/s, maximal $\upsilon \approx 700$ 1/s); M is mass 1 m³ of generator, kg/m³; γ is specific mass of the generator bogy, kg/m³ ($\gamma \approx 8000$ kg/m³); $c \approx 1/8$ correction coefficient, because average B = 0.5Bmax and ferromagnetic iron uses only about ½ engine volume. The maximal frequency determinates the ratio L/r, where L is inductance, r is electric resistance. That equals about 500 – 1000 1/s.

Example. Let us take the typical data B = 1 T, υ = 400 1/s, γ = 8000 kg/m³. We get maximal P/M = 2.5 kW/kg.

Typical high performance aviation generator has:

Type: ГТ-120ПЧ8	Power	Phases	Voltage	Currency	Frequency	Number of rev.	Mass

(Russian)	120 kW	3	208V	334 A	400 1/s	8000 in min	90 kg

The ratio for the usual aircraft generator equals 1.33 kW/kg. That is two times less than maximal possible. For our purposes that will be two times less because we need high voltage. But the high voltage transformer will weigh not less than electric generator. If aircraft has turbo 10,000 kW the magnetic propulsion system will weigh about 14 tons, 5 times more than turbojet. That is not acceptable in aviation and bad for a ground station. In addition, magnetic generator produces AC. The DC electrostatic generator weighs significantly less.

Electrostatic generator (EG).

Principal schema of electrostatic generator is in fig. 1.

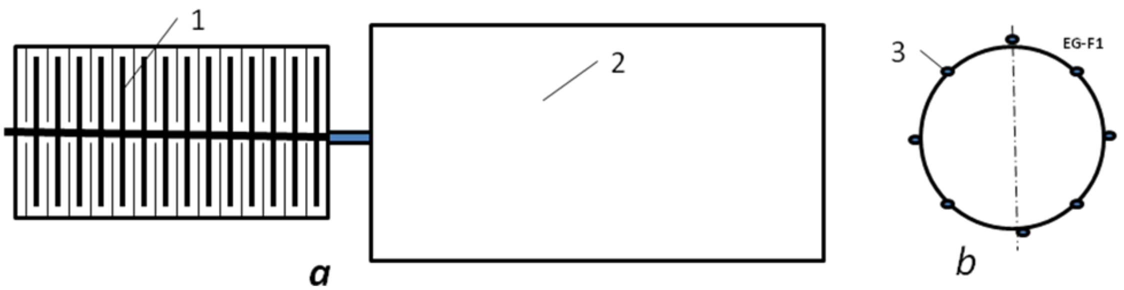

Fig. 1. Electrostatic generator. Notations: ***a*** – side view; *b* – forward view; 1 – electrostatic generator, 2 – steam, turbojet or other engine, 3 – electric collector.

The installation contains the electrostatic generator 1, the engine 2 (steam, turbo or other engine), electric collector 3 for charging the generator and getting the electricity.

The offer electrostatic generator is working the following way. There are stationary and rotate charged plates of capacitor (or two plates rotate in opposed direction). When charged plates remove from one to other, the voltage between them increases. When voltage reaches a need value, the plates discharges throw an outer load, After this they charge again and process is repeated.

Different types of electrostatic electric generator is known for about two centuries but it is not used because it produces very high voltage which is very dangerous for people and not suitable for practice and home devises. As a result, EG is studied very little and no power EG produces by industry.

The ratio power/mass of electrostatic generator for area S = 1 m^2 may be estimated by equation:

$$A=\frac{CU^2}{2},\quad C=\frac{\varepsilon\varepsilon_0 S}{d},\quad U=Ed,\quad P=\frac{A}{t},\quad M=\gamma\delta S,\quad \frac{P}{M}=\frac{\varepsilon\varepsilon_0 E^2\delta}{2\gamma d^2}V_a\,, \qquad (2)$$

where A is density of energy on 1 m^2 of the electrostatic (isolator plate) material J/m^2; C is capacitance of plate (one plate of condenser), F/m^2; U is voltage, V; ε (1 ÷ 3000) dielectric constant of plate matter; ε_0 = 8.85$\cdot 10^{-12}$ is permittivity, F/m; S is area of one plate, m^2; d is distance between plates (include thickness of one plate, m); P is power, W; t is time, s; M is mass 1 m^2 of generator plate, kg/m^3; γ is specific mass of the generator plate, kg/m^3 ($\gamma \approx$ 1800 kg/m^3), δ is clearance between plates, m; V_a is the average relative speed of two plates, m/s ($V_a \approx 0.5V$, where V is the peripheral disk (plate) speed).

Properties of some insulators in Table 1.

Table 1. Properties of various good insulators (recalculated in metric system)

Insulator	Resistivity Ohm-m.	Dielectric strength MV/m.. E_i	Dielectric constant, ε	Tensile strength kg/mm², $\sigma\times10^7$ N/m²
Lexan	10^{17}–10^{19}	320–640	3	5.5
Kapton H	10^{19}–10^{20}	120–320	3	15.2
Kel-F	10^{17}–10^{19}	80–240	2–3	3.45
Mylar	10^{15}–10^{16}	160–640	3	13.8
Parylene	10^{17}–10^{20}	240–400	2–3	6.9
Polyethylene	10^{18}–5×10^{18}	40–680*	2	2.8–4.1
Poly (tetra-fluoraethylene	10^{15}–5×10^{19}	40–280**	2	2.8–3.5
Air (1 atm, 1 mm gap)	-	4	1	0
Vacuum (1.3×10^{-3} Pa, 1 mm gap)	-	80–120	1	0

*For room temperature 500–700 MV/m.

** 400–500 MV/m.

Source: Encyclopedia of Science & Technology[9] (Vol. 6, p. 104, p. 229, p. 231).

Note: Dielectric constant ε can reach 4.5 – 7.5 for mica (E is up 200 MV/m); 6 – 10 for glasses (E = 40 MV/m) and 900 – 3000 for special ceramics (marks are CM-1, T-900) (E = 13 – 28 MV/m). Dielectric strength appreciable depends from surface roughness, thickness, purity, temperature and other conditions of material. It is necessary to find good insulating materials and reach conditions which increase the dielectric strength.

The safe peripheral disk speed may be estimated by equation $V = (\sigma/\gamma)^{0.5}$ where σ is safety tensile stress (N/m²), γ is specific weight, kg/m³. The disk may be reinforced by fiber having high tensile stress.

Let us consider the following experimental and industrial fibers, whiskers, and nanotubes:

Experimental nanotubes CNT (carbon nanotubes) have a tensile strength of 200 Giga-Pascals (20,000 kg/mm²), Young's modulus is over 1 Tera Pascal, specific density γ=1800 kg/m³ (1.8 g/cc) (year 2000). For safety factor n = 2.4, σ= 8300 kg/mm² = 8.3×10^{10} N/m², γ=1800 kg/m³, $(\sigma/\gamma)=46\times10^6$, K = 4.6. The SWNTs nanotubes have a density of 0.8 g/cc, and MWNTs have a density of 1.8 g/cc. Unfortunately, the nanotubes are very expensive at the present time (1994).

For whiskers C_D σ = 8000 kg/mm², γ = 3500 kg/m³ (1989).

For industrial fibers σ = 500 – 600 kg/mm², γ = 1800 kg/m³, σ/γ = $2{,}78\times10^6$, K = 0.278 – 0.333,

Figures for some other experimental whiskers and industrial fibers are given in Table 2.

Table 2. Properties of fiber and whiskers

Material Whiskers	Tensile strength kgf/mm²	Density g/cc	Material Fibers	Tensile strength MPa	Density g/cc
AlB_{12}	2650	2.6	QC-8805	6200	1.95

B	2500	2.3	TM9	6000	1.79
B_4C	2800	2.5	Thorael	5650	1.81
TiB_2	3370	4.5	Allien 1	5800	1.56
SiC	1380–4140	3.22	Allien 2	3000	0.97

See Reference [9] p. 33.

Example: Let us estimate ratio *P/M* of the electrostatic generator by equation (2). Take the electric intensity $E = 10^7$ V/m, area of the disk 1 m^2, thickness of the disk 0.003m, clearance between disks δ = 0,002 m, (d = 0.005 m), V = 500 m/s, γ = 1800 kg/m^3, ε = 3. Substitute these data in equation (23) we get *P/M* = 53 kW/kg. That means the electrostatic generator (motor) of equal power will be in 20 times less than magnetic generator (motor). The 10,000 kW electrostatic generator (motor) will weigh only 400 kg (200 disks). And additional the electrostatic generator produces high voltage direct (constant) electric currency (DC).

Air friction in electrostatic generator and its efficiency.

Let us estimate ratio of the air friction/produced power 1 m^2 of disk the electrostatic generator. Compute the friction, produced power and efficiency:

$$P_f = 2FV_a, \quad F = \varsigma\frac{V_a}{\delta}, \quad P_f = 2\frac{\varsigma V_a^2}{\delta}, \quad P = \frac{\varepsilon\varepsilon_0 E^2}{2}V_a, \quad \eta = 1 - \frac{P_f}{P} = 1 - \frac{4\varsigma V_a}{\varepsilon\varepsilon_0\delta E^2}, \qquad (3)$$

where P_f is power of friction 1 m^2 of disk, W/m^2; F is friction force 1 m^2 of disk, N/m^2; V_a is average disk speed, m/s; ς is viscosity of the gas (for air $\varsigma = 1.72\cdot10^{-5}$ Pa·s, for hydrogen $\varsigma = 0.84\cdot10^{-5}$ at atmospheric pressure and $T = 0^{o}$C); P is power produced 1 m^2 of disk, W/m^2; ε is dielectric constant of plate matter; $\varepsilon_0 = 8{,}85\cdot10^{-12}$ is electric permeability, F/m; δ is clearance between disk, m; E is electric intensity, V/m ; η is efficiency of generator related to air friction.

Example: If V_a = 250 m/s; $E = 2\cdot10^6$ V/m; δ = 0.002 m, then η = 0.92.

The coefficient of gas friction weak depends from the pressure and temperature. If we change the air into the electrostatic generator by hydrogen, the loss of friction decreases in two times. If we create a vacuum in the electrostatic generator, the gas friction will be zero and the safety electric intensity is increased in many times.

Transformer direct currency into alternative currency and back.

Principal schema of the offered electronic transformer - high voltage DC in low voltage DC or DC in AC and back is presented in fig.2.

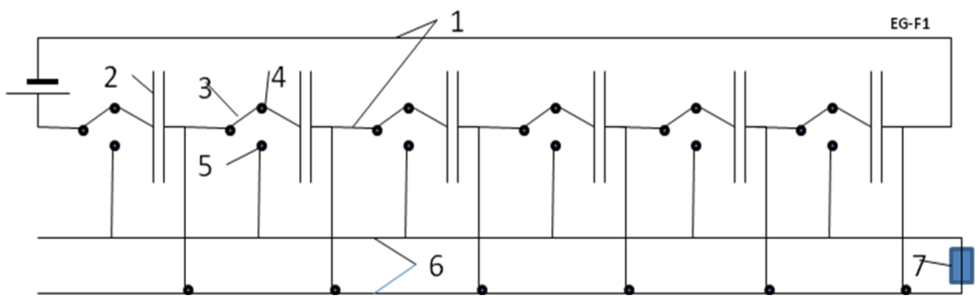

Fig.2. Principal Schema of the offered transformer -- high voltage DC in low voltage DC or DC in AC and

back. *Notations*: 1 – high voltage line, 2 – condensers (capacitor), 3 – two positions electronic switch, 4 – contact the high voltage line, 5 – contact the low voltage line, 6 – low voltage line. 7 - outer electric load.

The installation contains two line (high voltage 1 and low voltage 6), the series of the capacitors 2 and series of the electronic switches 3. Switches 3 have a two position 4, 5. In position 4 the switches connect the capacitors in the series connection; in position 5 the switches connect the capacitors in the parallel connection. In position 4 every capacitor has voltage U/n , where U is voltage of line 1, n is number of capacitors in series. In position 5 the voltage is U/n in line 6, but an electric currency increases in n times. As the result we decrease voltage U in n times, but increases the currency i in n times.

The offered transformer can work in back direction: increases the voltage of DC to very high voltage. Connections the capacitor and electronic switches we can transform the direct currency in the any alternative currency, any frequency, any phases, any form of waves (directly and back).

The possible frequency determined by ratio $1/rC$, where C is capacitance of capacitor, r is Ohm electrical resistance. That equals about $10^8 – 10^9$ 1/s.

SUMMARY.

The author offers a cheap electrostatic generator produced a high voltage direct currency (DC) and electronic transformer, which converts high voltage DC into low voltage DC or any alternative electric currency (or back). He shows a transmission of the high voltage direct currency (DC) to long distance has big advantages in comparison with the current transmission by the alternative current (AC). The electrostatic generator (installation) is cheaper, more efficiency and more appropriate for long distance transmission than current equipment for AC. one hundred years ago generating electricity by the magnetic method was easy and development led to a system centered on AC. Now AC is the dominant method. That is only a result of the quirks of electricity's historical development. But development of electronics in recent years makes possible the design of powerful electrostatic generators and electronic transformers.

In present time it is achievable to research and develop (R&D) the high voltage electrostatic generators and inverters of high voltage DC in low voltage DC and in AC and using the old AC lines and devices.

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Author offers a cheap high voltage electrostatic generator and transformer of high voltage DC to low voltage DC and DC in AC (any frequency and phases) and back. That may be adopted gradually and it will give significantly savings of electricity and energy.

Researches related to this topic are presented in [1]-[13].

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Professor A.A. Bolonkin is the author of more than 200 scientific articles and books, and has 17 inventions to his credit. His most notable books include: Non-Rocket Space Launch and Flight (Elsevier, 2006) http://www.scribd.com/doc/203941769/ ; New Concepts, Ideas, and Innovations in Aerospace, Technology and Human Life (NOVA, 2008); Human Immortality and Electronic Civilization (Lulu, 1994); Femtotechnologies and Revolutionary Projects. Lambert Academic Publishing, Germany, 2011, 538 p. http://www.scribd.com/doc/75519828/ , Life and Science. Lambert, 2011, 205 pgs.