Dielectrodynamics and applications

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Part one

Dielectric blade comb piston mechanic-electric bi-direction converter

First version

Abstract

The electric vs. mechanic bi-directional power conversion application has been traditionally and asymmetrically favoring at magnetic element as energy caching and buffering bridge, e.g. the electric motors and generators that are also abstracted as electromechanical devices. The theory behind those omnipresent electromechanical devices or equipments is electrodynamics.

Based on recent fast development of high energy density dielectric materials, my inventions are to be a game changer: let electrical field alone to take the heavy duty of electromechanical utilities, and let “dielectrodynamics” replace electrodynamics.

Of the most importance is the key limitless high voltage generator, which can cover full gamut of voltages from volts to kilovolts (KV), megavolts (MV), even gigavolts (GV), and what we need, is just to provide necessary space occupancy and mechanic work acting on dielectric blade comb-like piston. Either motor or generator can be re-invented with this core dielectrodynamic module.

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§1. Introduction

The electric vs. mechanic bi-directional power conversion application has been traditionally and asymmetrically favoring at magnetic element as energy caching and buffering bridge, e.g. the electric motors and generators that are also abstracted as electromechanical devices, and the backing theory is electrodynamics.

Based on the fast development of high energy density dielectric materials, it is the high time to change the game: let electrical field alone to take the heavy duty of electromechanical utilities, and let "**dielectrodynamics**" replace electrodynamics.

Of the most importance is the limitless high voltage generator, which can cover full gamut of voltages from volts to kilovolts (KV), megavolts (MV), even gigavolts (GV), as long as necessary space occupancy and mechanic work are secured to assist dielectric piston or blades displacement.

As the nature of such an electric power supply, it is fit for pulse application, such as Z-pinch, particle accelerator, nuclear ignition, fusion reactor, ornithopter etc. Civil application is also possible, such as harvest wind power, pulse heating, electric drive, but regular non-pulse application may need further power smoothing or conversion.

§2. Background of pertinent technologies

The order of magnitude of voltage matters.

The current best choice of **HV** (**H**igh **V**oltage) supply, such as Marx generator, Van de Graaff generator, Tesla coil, the magnitude therein is mostly a few of **MV**s, none can march into the **GV** (gigavolt) domain, even nor most natural lightning.

It is reported that regular lightning can reach **100MV** and rarely **1GV**; and so far, the man-made highest voltage record is still hold by the Oak Ridge National Laboratory's landmark tandem electrostatic accelerator: **32MV**.

Although Marx generator no voltage limit in theory and no magnetic involvement, however it suffers from low efficiency in recharge and discharge, as worse as too many discrete high voltage capacitors occupying too much space, so as hopeless to achieve arbitrary high voltage.

Van de Graaff generators are of electrostatic type, and its ability of voltage anteing up is also frustrated by some factors, though it was the high voltage record keeper.

Tesla coil can also generate **MV-level** high **AC** (alternating current) voltage, however almost all super voltage applications are only in favor of **DC** (direct current), e.g. particle accelerator, unfortunately high voltage rated rectifier diodes are so few or expensive.

The scientific community is now focusing at the research of **LTD** (Linear Transformer Driver) high voltage (**MV-level**) and pulse high current (**MA-level**) generating technology, for example, the Sandia National Laboratory for her next **Z-**machine power supply.

As the **LTD** voltage adders need magnetic involvement in generation of huge power pulse, so it is doomed to face the cumbersome volume and expensive investment, perhaps more other technical difficulties, such as the unavoidable high parasitic inductance prohibiting the pulse width narrowing, etc.

Although the **GeV** and **TeV** accelerator can be built, however, a single **DC** power supply can never cope with it, instead of cascade **RF** powered LINAC, as well as the huge cost may be almost a financial black hole.

In the adventure of fusion, the magnetic inertial confinement Tokomak solution still struggles for the sustaining time and energy breakeven balance.

And almost all electromechanical devices, such as electric motors, generators, etc., still need the co-operation or interaction between the inherent electric fields and the induced or permanent magnetic fields.

If we can economically access **GV-level** or above electricity, or even if we can make mid-range voltage utilities but with light weight feature resulted by elimination of expensive rare earth magnetic materials and heavy copper coils, then a new world will emerge, especially both the fusion new epoch and the magnetic-free revolution of electromechanical equipments will loom and boom.

Motivated by such a great cause, my exploration is aiming at seeking feasible voltage-transforming methods to get rid of magnetic involvement and to break the prior record of high voltage as extensive as possible.

The shared play stage of electric and magnetic fields are now going to be monopolized by electric field only, can such a fresh electromechanical device or transformer still function as usual?

Yes, it can! After following brief introduction, I will show how to realize it in detail soon.

As electric energy can be stored either in pure electric field, or in pure magnetic field, or in hybrid of electric and magnetic fields, so even no longer available for the regular mode of electric and magnetic fields interplay together, the pristine electric-field-only device can still deal with energy transaction in circuit.

Intuitively dielectric-conditioned capacitors can cache electric energy or conduct energy transaction via discharge, and those behaviors and actions can be completed in pure electric field only without magnetic involvement, though dielectric media are insulators.

So in brief, it is proved true that **dielectric materials can play the electric-field-only monologue in any utility application.**

Now the only leftover concern is that whether the electric-field-only apparatus can be as powerful as the regular electric plus magnetic hybrid-field apparatus.

This concern will be thawed by the good news: in 2010, the **Pennsylvania state university** invented a new dielectric material which energy density is the **top-rated** and **surpasse**s far more over the top affordable magnetic energy density. The publication of "DIELECTRIC BREAKDOWN OF ALKALI-FREE BOROALUMINOSILICATE GLASS THIN FILMS" heralds its coming.

§3. Why is magnetism-involved high voltage system bottlenecked about MV-level?

Magnetism-involved transformers always run on inductive effect where electromagnetic oscillation occurs, and oscillation results in **AC** in circuit, but for the extreme high voltage application, the **DC** is always preferred, so rectification should be done.

Diodes are applied for the purpose of rectification, and most diodes are made of semiconductors, the others vacuum tubes. As unidirectional passage electric component, a diode should withstand reverse voltage. For low voltage applications, never worry about it, but for extreme high voltage over specific threshold, reverse breakdown failure becomes a serious problem.

Diodes seem impossible or extremely difficult to withstand extreme high voltage larger than million volts. That is why the Tesla coil high voltage generator rarely used in particle accelerator, and that is also why the doomed bottleneck does exist for all magnetism-involved high voltage generator.

Of course, the dielectrodynamic based magnetism-free high voltage generator has no such a bottleneck.

§4. Energy density (ED) matters.

For the industry-favored magnetic energy, the **ED** can be calculated via formula $\mathbf{B^2/(2\mu)}$, where **B** stands for magnetic strength, and **μ** permeability, $\mathbf{4\pi*10^{-7}H/m}$ for vacuum space. For the economic choice of max accessible **B**, e.g. **B = 2 Tesla**, we have **ED =** $\mathbf{1.6*10^6\ J/m^3 = 1.6MJ/m^3}$.

For the dielectric space, the $\mathbf{ED = \epsilon\epsilon_0 E^2/2}$, where **E** stands for electric field strength, ϵ_0 = vacuum permittivity = $\mathbf{8.85*10^{-12}F/m}$, **ϵ** = relative dielectric constant to vacuum or air.

If taking **E** = **3MV/m** as the breakdown limit of the regular atmosphere space, we can only get $\mathbf{40J/m^3}$, of course it is extreme shy to compare with magnetism.

But nowadays we have more and more better choices of dielectric materials to cache and buffer energy, even water is not too bad choice if its other demerit could be overcome, because of its high **ϵ = 80** and high breakdown electric field **E = 60MV/m**, **then ED = 1.3MJ/m^3**, on par with the aforementioned magnetic **ED**.

Other excellent dielectric materials: piezoelectric ceramic, **ED = 16MJ/m^3**; **AF45**, invented by Pennsylvania university, **ED = 38.5MJ/m^3**. Specially, **AF45** is described by media ScienceDaily News as "Storing A Lightning Bolt In Glass For Portable Power", because its breakdown limit can reach the incredible **1.2GV/m**!

In fact, energy density also reflects the specific pressure. This can be validated by checking the dimension in **SI** unit: **J/m^3 = Nm/m^3 = N/m^2 = Pa**, **J** -- Joule, **m** -- meter, **N** – Newton (**1kg = 9.8N**), **Pa** -- Pascal.

The western favored pressure unit are bar and psi (pound per square inch), and **0.1MPa = 1bar = 14.5psi**. So the abovementioned magnetic energy density is also the magnetic pressure **1.6MPa = 16bar = 232psi**, as well as the air **40Pa = 0.0058psi**, the **AF45** electric pressure **38.5MPa = 385bar = 5582psi**. As a common sense, car tire is about **30psi**, and commercial hydraulic system about **2000psi**, hence we see the **AF45** electric pressure is even more powerful than a crane's hydraulic system.

No wonder almost all electric power systems utilize magnetism, because its decent pressure **232psi** sounds strong enough for general dynamic applications, despite only about **10%** strength of hydraulic system!

Now that the new generation of dielectric materials possesses such a high electric pressure up to **5582psi** ≫ regular magnetic pressure **232psi**, why to hesitate to utilize them? The answer is because the current industry is not adept to make use of the electrostatic force.

My research shows that mechanical work can be efficiently converted to electrostatic energy with very little loss.

§5. Reciprocal converter of mechanical to electrostatic energy

Firstly, let us review the capacitor's capacitance and its energy storage.

For the simple parallel-plate capacitor, its capacitance $\mathbf{C = \epsilon\ \epsilon_0 A/d}$ where **A** -- the plate's area, **d** -- the distance of plates, and its total stored energy = $\mathbf{Volume * \epsilon\epsilon_0 E^2/2}$.

As the energy is proportional to square of electric field **E,** but linear with **ϵ**, and **E = V/d, V** --voltage, so increasing **V** for higher energy density is more sensitive than increasing **ϵ**.

By changing **ϵ or E or volume,** we can change the stored energy, but no way to alter material dielectric breakdown strength because of $\mathbf{E_{max}}$ always limited, except simply changing the voltage configuration under allowable $\mathbf{E_{max}}$.

Changing **ϵ** can be done by mechanical displacement or temperature.

But the thermoelectric efficiency is quite low because of its high entropy, mostly **< 2%,** even the most excellent mineral tetrahedrite **< 7%,** so just forget temperature method.

Mechanic energy is low entropy and can be high efficiently converted to electric energy.

Luckily, we have a great range of **ϵ** to select; the highest **ϵ** even may hit the value of about $\mathbf{10^{10}}$, e.g. the special formulated electrolyte materials in super capacitors, though their rated voltage is low.

Nowadays low cost high **ϵ** between **1000** and **100000** are used everywhere, such as the piezoelectric material in the cheap cigarette lighter. The regular high voltage rated solid material, e.g. $\mathbf{PbMgNO_3 + PbTiO_3}$, its high **ϵ** = **22600**.

The easy mechanic energy carrier or transmitter is piston, however no necessary to be the traditional cylindrical shape, in my dielectric media displacement inventions, the best shape of dielectric piston is thin slices or blades with rectangular or rotary transverse section.

By input mechanical work, we can change, or say, displace different materials inside the capacitor with great **ϵ** change. As per energy conversation law, we have equation:

Initial stored energy (state 1, $\mathbf{Volume * \epsilon_1\epsilon_0 E^2/2}$**) + Mechanic energy =**

Final stored energy (state 2, Volume*$\epsilon_2\epsilon_0E^2/2$) + Friction loss.

It means the incipient medium with dielectric constant ϵ_1 is displaced by medium ϵ_2.

For simplification, we can omit the negligible friction loss, as friction reduction engineering methods are always available to choose and apply.

We **do need** initial energy pre-stored in the capacitor. If not, the dielectric material will be not pinched by any electrostatic force, so no way to absorb mechanic work for a loose free dielectric medium.

The initial energy is provide by **initial electric field** or **exciting voltage**, in mimic of electric motor or generator jargon where **exciting current** is needed to initialize magnetic field if no permanent magnet is used.

We do not demand too much initial energy from the said exciting voltage, just like a motor or generator usually draws small fractional basic current for keeping basic exciting magnetic field.

Of course, special permanent **electret** material can be used, so no need to input it with initial energy, instead of collecting charges from free space, but hopeless of heavy duty.

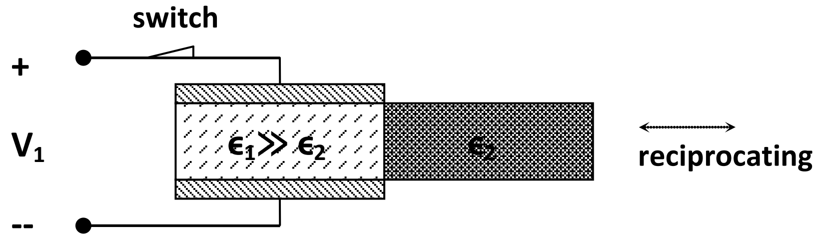
For maximal mechanic energy harvest, we wish the final stored energy is **far more than** initial stored energy.

Usually, the higher the ϵ, the higher polarization rate of bipolar moments, then more charges will be **locked** on the plates. Only by displacing higher ϵ_2 medium with lower ϵ_1 medium**,** then there are more **unlocked** free charges accumulated with potential to push to higher voltage, though the total locked and unlocked charges are conservative.

The higher the voltage increase, the more tightly the plates are pinched, then the more mechanic work you have to input, otherwise the medium is loose and free to move.

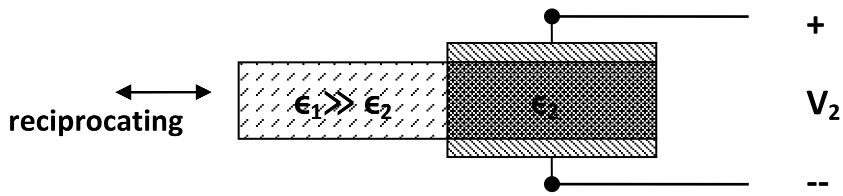
Fig. 1 shows an abstract dielectric media reciprocally displaceable capacitor with mechanical input and voltage output. The electrode plates are like as “stators”, and **2** joined dielectric materials play lively as a laminating board “piston”. Both stators and pistons are in shape of rectangle.

a. medium ϵ_1 inside capacitor



V_1 is the exciting voltage

b. medium ϵ_2 is switched into capacitor



$V_2 = V_1*(\epsilon_1/\epsilon_2)$ generated

by moving ϵ_1 and ϵ_2 combined piston

c. medium ϵ_2 liquid, ϵ_1 solid soaked

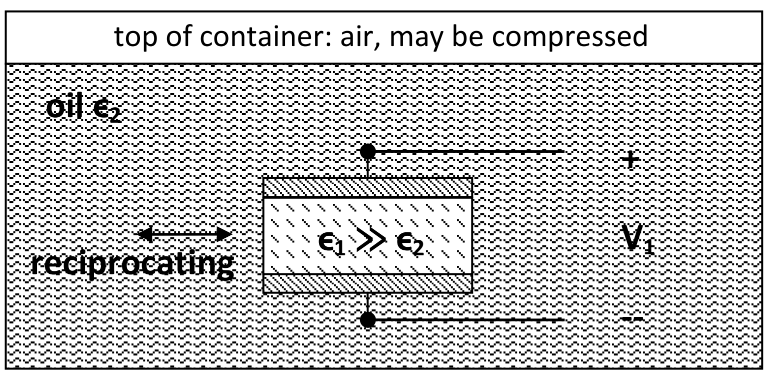


Fig. 1: dielectric media reciprocating displaceable capacitor voltage transformer

The Greek letter **ϵ** also stands for material's dielectric constant, and as my protocol and as showed in all drawings, $\boldsymbol{\epsilon_1}$ is always larger than $\boldsymbol{\epsilon_2}$**.**

The sub-figure **1.a** is the moment that dielectric medium $\boldsymbol{\epsilon_1}$ fulfill inside capacitor, and the capacitor is charged by excitation voltage $\mathbf{V_1}$ via dedicated switch that serves $\boldsymbol{\epsilon_1}$ only; sub-figure **1.b** medium $\boldsymbol{\epsilon_2}$ is the insider after exerting force, and the excitation voltage is amplified by ϵ_1/ϵ_2 times; sub-figure **1.c** medium ϵ_2 is liquid, ϵ_1 solid, and whole capacitor is soaked under oil in a commeasurable container.

Although alternative setting possible: dielectric combination immoveable & electrodes movable, anyway such is not convenient, as electrodes are often hooked with wires.

§6. Work stroke analysis

So much for the qualitative description, now I quantitatively find how high the voltage can increase, and how many mechanic work is converted to electrostatic energy after displacement event, aka "work stroke" in mimic of internal combustion engine jargon.

As total charges conserve during displacement, and constant plate area, plate distance, volume, so does charge density **CD**, that means $CD = \epsilon_1\epsilon_0 E_1 = \epsilon_2\epsilon_0 E_2$, $E_1 = V_1/d$, $E_2 = V_2/d$ -- electric field strengths of initial and final respectively, V_1, V_2 -- voltage of initial and final respectively.

Then we deduce that: $V_2 = (\epsilon_1/\epsilon_2)*V_1$. For a reasonable design, $\epsilon_1 \gg \epsilon_2$, hence $V_2 \gg V_1$.

For convenience, hereafter, ϵ_1 is always used to stand for high permittivity dielectric medium, and ϵ_2 for low one, even this protocol is also applied universally in all figures.

As to the capacitance, $C_1 = \epsilon_1\epsilon_0 A/d$, $C_2 = \epsilon_2\epsilon_0 A/d$, so $C_2 = (\epsilon_2/\epsilon_1)*C_1$, thus $C_2 \ll C_1$.

According to the formula of total energy of capacitor: $\text{the\_final\_energy} = (C_2 V_2^2)/2 = (\epsilon_2/\epsilon_1)*C_1*[(\epsilon_1/\epsilon_2)*V_1]^2/2 = (\epsilon_1/\epsilon_2)*(C_1 V_1^2)/2 = (\epsilon_1/\epsilon_2)*\text{the\_initial\_energy}$.

Obviously, it is just what we expect: $\text{the\_final\_energy} \gg \text{the\_initial\_energy}$.

Assuming friction is zero, hence we have to input mechanic work:

$[(\epsilon_1/\epsilon_2) - 1]*\text{the\_initial\_energy}$ to cover the electrostatic energy increase. As $\epsilon_1/\epsilon_2 \gg 1$, then $[(\epsilon_1/\epsilon_2) - 1]*\text{the\_initial\_energy} \approx (\epsilon_1/\epsilon_2)*\text{the\_initial\_energy} = \text{the\_final\_energy}$, i.e., the final stored electrostatic energy is almost the total contributed mechanic work, and the initial energy, aka "exciting energy", is just a small token or trigger!

Further, we can calculate the average force to drag the dielectric media.

Assume the capacitor is in shape of rectangle of width **W** and length **L**, to completely displace the initial medium ϵ_1 along the length-wise, the mechanism should be exerted the average force:

F = [(ϵ_1/ϵ_2) – 1]*the_initial_energy/L

Now, we understand that the higher ϵ_1 medium is set to work under low voltage for exciting initial electrostatic field, and the lower ϵ_2 medium as the energy real bearer working under high voltage, and then we also understand that only the low ϵ_2 medium's maximum energy density is utilized, but the capability of high ϵ_1 medium's energy density is under-employed because of its purpose of initial excitation electric field with small token energy.

One may be interested in the transition of displacement. Now, let's deal with it.

We use χ to stand for the percentage of transition completeness, and then value **1 or 100%** means medium ϵ_1 is totally displaced by ϵ_2. Hence, the transient voltage, capacitance, and accumulated energy all are the functions of the parameter χ.

So long as we recognize charge conserve restriction, following functions can be obtained:

The transient capacitance function: $C(\chi) = C_1*[\epsilon_1(1-\chi) + \epsilon_2\chi]/\epsilon_1$

The transient voltage function: $V(\chi) = V_1*\epsilon_1/[\epsilon_1(1-\chi) + \epsilon_2\chi]$

The transient energy function:

the_transient_energy(χ) = the_initial_energy*ϵ_1/[ϵ_1(1- χ) + ϵ_2 χ]

Substituting $\chi = 1$, we get the same results of the final state with the earlier expressions.

If drawing the respective function graphs, we can find: only capacitance is linear function, the voltage and energy are both non-linear with very steep curve while χ approaching **100%**. That means no big force is needed during incipient displacement action, but strong force nearby ending.

Fig. 2 shows the waveform of full loaded voltage output. It hints that the voltage change between the capacitor electrodes is nonlinearly related with dielectric displacement.

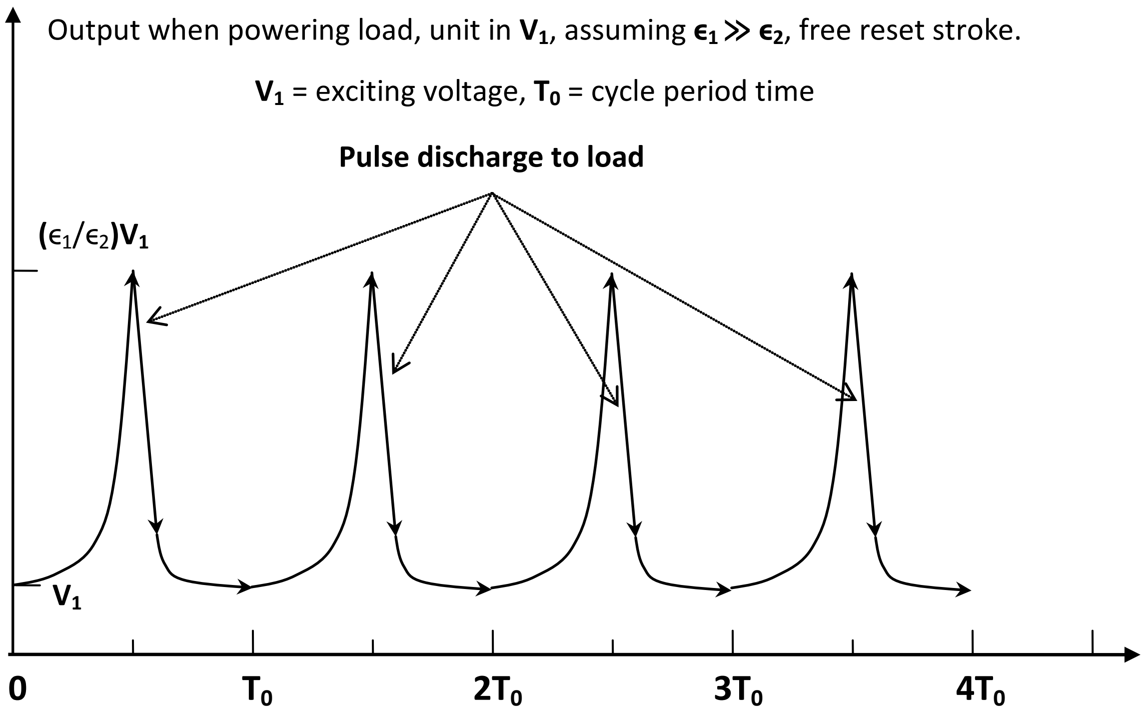


Fig. 2: full loaded voltage output

In brief, when dielectric medium in capacitor is switched from high permittivity ϵ_1 to low one ϵ_2, such a displacement needs input of mechanic energy, and in turn this mechanic energy will be converted to electrostatic energy, thus voltage will be multiplied greatly by ϵ_1 / ϵ_2, in spite that no charging current follow is infused to the capacitor.

§7. Reset stroke analysis

For a utility, it needs to work cycle by cycle constantly. So when the "work stroke" finished, we see the high voltage, and then need re-start the next cycle.

I define: the reset stroke is referred to the "reverse" displacement that high dielectric constant medium re-enters the capacitor after the low one goes out of the capacitor.

Obviously if the high voltage energy is not taken away, or say, consumed elsewhere, then no need to re-input mechanic energy for reset of dielectric medium ϵ_1, because the powerful resilient force will act, and the media combination strip will be accelerated backwards, that means the stored electrostatic energy will be reversed to mechanic energy, and it may be not what we desired.

If the generated electric energy is not used, then the reset max velocity **Ve** of the media movement can be resolved via energy conservation law:

0.5*m*Ve*Ve = the_initial_energy*[(ϵ_1/ϵ_2) -1], **m** -- the mass of the dielectric blades.

Ve = {2*the_initial_energy*[(ϵ_1/ϵ_2) -1]/m }$^{0.5}$

By gentle holding back media reset, and let media slowly finish the reset stroke in small constant velocity, then we can prevent the media from gaining significant kinetic energy, but it will result in higher voltage: $V_1\ (\epsilon_1/\epsilon_2)^{0.5}$, here V_1 is the original exciting voltage.

If always idling the output and holding back during reset stroke, after the next cycle work stroke, new voltage is $(\epsilon_1/\epsilon_2)^{1.5}*V_1$, and if so on, the next cycle reset voltage $(\epsilon_1/\epsilon_2)*V_1$, this indicates a gradually augmented tooth-shape voltage curve in timeline.

For the said tooth-shape voltage situation, there is a set of general formula to calculate the **nth** cycle peak voltage and reset voltage as follows:

$V_{n\text{-peak}} = V_1*(\epsilon_1/\epsilon_2)^{(n+1)/2}$, and $V_{n\text{-reset}} = V_1*(\epsilon_1/\epsilon_2)^{n/2}$

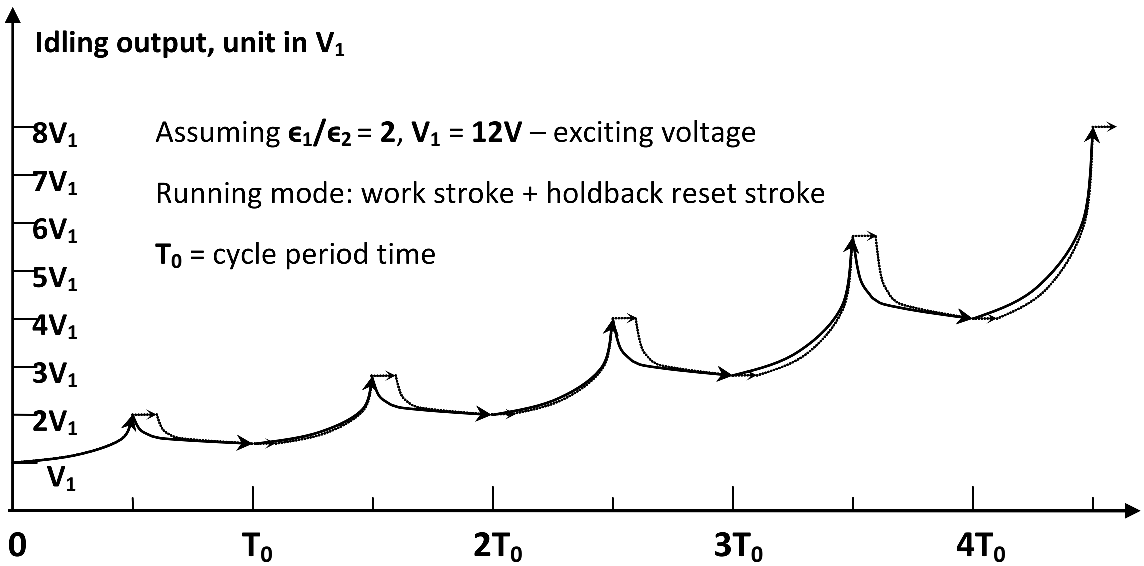
Unless special design, otherwise, the above run mode will damage the media if voltage is over the breakdown voltage.

In fact, of the two dielectric materials pair, it is the **vulnerable one** with lesser breakdown electric field strength that determines system maximal attainable voltage.

Usually even the applied field exceeding the limit, breakdown event can still not occur if the stay time is too short because electron avalanche is an accruing process, so it's possible to temporarily "**overclock**" dielectric materials for extra energy storage.

Fig. 3 shows the idling voltage output of mode of work stroke plus holdback reset stroke.

If the high voltage energy is totally consumed or transferred elsewhere, i.e. $V_2 = 0$, then reset to ϵ_1 may need basic minimal input of mechanic energy to overcome friction and keep reasonable retraction velocity unless the type is not reciprocal but rotary generator with usable remnant inertial energy because no cached electric energy can assist, but the **token electric field** should be regenerated by low exciting voltage for the next cycle to run.



Dotted lines show the input/output window if media over-cover electrodes

Fig. 3: idling voltage output of mode of work stroke plus holdback reset stroke

However we can take accurate control to the output high voltage discharge in order to omit the tedious re-excitation or possible minimal mechanic energy input, it means that only one time is necessary to excite initial field during uptime. In this case the post-discharge remaining voltage should keep the remaining energy equal to the initial excitation energy:

$$\mathbf{Volume*\epsilon_1\epsilon_0E_1^2/2 = Volume*\epsilon_2\epsilon_0E_{remain}^2/2}$$

i.e. $\mathbf{V_{remain} = V_1*(\epsilon_1/\epsilon_2)^{0.5}}$

If the remaining voltage is less than the $\mathbf{V_{remain}}$, it is necessary to partially recharge the initial voltage to the same $\mathbf{V_1}$, if every cycle needs same performance.

In fact, the initial energy just a small token, re-exciting is not a big deal, so never mind to fully discharge the high voltage output if accurate control is difficult.

If partial output consumption does occur but the leftover voltage is still greater than

V_{remain}, perhaps it is a good idea to directly dump the remained small energy until **V_{remain}** is seen (or **0** if not care about re-excitation) by simply short connecting the positive and negative terminals for smooth reset.

By comparison, the conventional electromechanical device even eats more mechanic energy by the inevitable magnetic material eddy current heating.

The most spectacular output energy take-away method may be the **Z-pinch** discharge; at least, that is the preferred choice for **Sandia National Lab**.

From above studying, we can conclude that the high voltage output is limitless, **GV** (Gagavolt), **TV** (Teravolt), even **PV** (Petavolt) are never a dream, provided only the dielectric breakdown strength **E_{max}** should be respected, because **$V = E_{max}*d$** and the parameter of distance **d** unlimited, as long as space is not restrained, such as in **km** level.

§8. Rotary converter of mechanical to electrostatic energy

As rectangle configuration is good only for reciprocal displacement, but if rotary motion is preferred, then circle configuration is needed.

Fig. 4 shows some variants of rotary displaceable capacitor mechanic-voltage transformer. Similar to **fig. 1**, instead of laminating board piston, the moving parts change to rotatable laminating disk, and instead of pull or push, rotating torque is exerted via shaft.

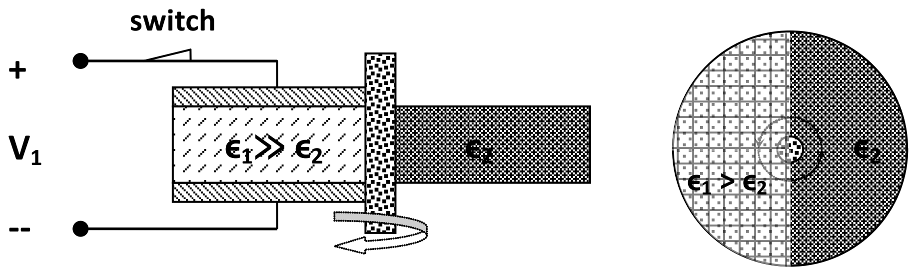
For **2**-patal laminating disk, the electrode plates are semicircle disks.

Sub-figure **4.a** shows the moment that medium **ϵ_1** is lodging inside capacitor and charged by voltage exciter that serves **ϵ_1** only.

Sub-figure **4.b** shows medium **ϵ_2** is switched into capacitor after **180°** rotation, and capacitor output voltage is enlarged to **$V_1*(\epsilon_1/\epsilon_2)$.**

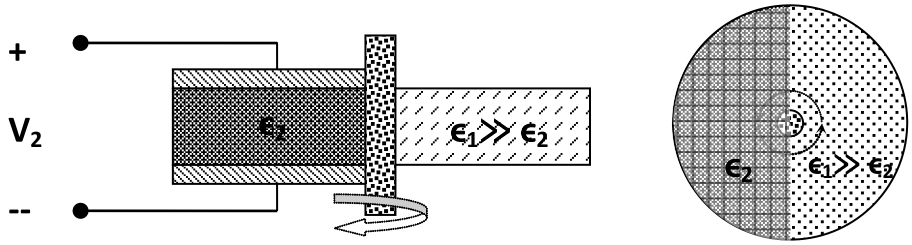
In sub-figure **4.c,** medium **ϵ_2** is liquid, **ϵ_1** solid, and whole capacitor is soaked under oil in a commeasurable container. In this case, the rotor is a semicircle disk with shaft.

a. medium ϵ_1 inside capacitor for the simplest 2-petal model



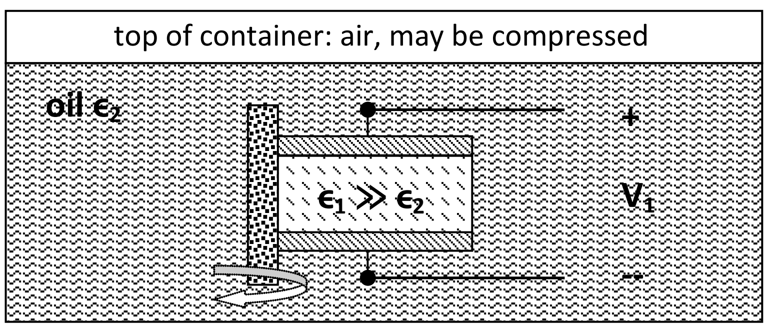
V_1 is the exciting voltage **top view**

b. medium ϵ_2 is switched into capacitor after 180° rotation

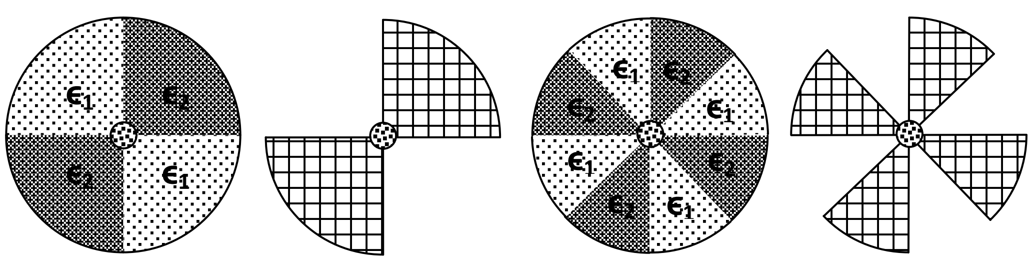


$V_2 = V_1 * (\epsilon_1/\epsilon_2)$ generated **top view**

c. medium ϵ_2 liquid, ϵ_1 solid soaked



d. dielectric multiple petals interlace is allowed, e.g. **4** & **8** petals



Electrode plates area = **50%** of disc area for many applications

Possible to combine multi-output by applying **3** or more media, e.g **10KV+100KV**.

Fig. 4: dielectric media rotary displaceable capacitor voltage transformer

Further, sub-figure **4.d** visualizes multiple petals interlace laminating dielectric disk rotor, e.g. **4** and **8** petals. As ad hoc, the **2** check-pattern rotors comprise one medium in **2** and **4** petals, and only for use in vacuum or submersion of fluid, e.g. air, oil, etc.

In fact, one shaft can host many such dielectric disk modules if needed, for example, both **10KV** and **100KV** double modules.

§9. Geometry consideration

Unlimited high voltage output sounds good, but $C = \epsilon_2\epsilon_0 A/d$ is never unconditionally true and accurate, unless we can try our best to let the plate area $A \gg d*d$.

However assuring $A \gg d*d$ may spoil our unlimited voltage $V = E_{max}*d$, because the former needs parameter **d** as short as possible, but the latter **d** as long as possible.

This embarrassment can be overcome by inserting a large number of intermediate plates as many as necessary, and then the whole capacitor is equivalent to a series of cascading capacitors. For uniform insertion of **N** plates, every single element capacitor has equal thickness $d_0 = d/N$. Such a configuration is just like as an antique tunable capacitor in old school style radio receiver, if medium is simply the air.

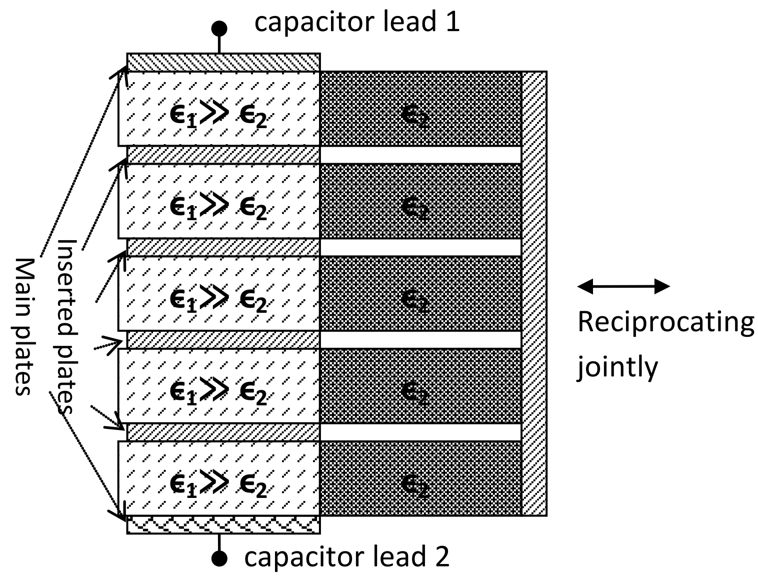
Because of the similarity between the dielectric slices and blades, sometimes the dielectric piston is also figuratively referred to **dielectric blade comb** piston.

Do more or less intermediate plates matter? The answer is: It depends.

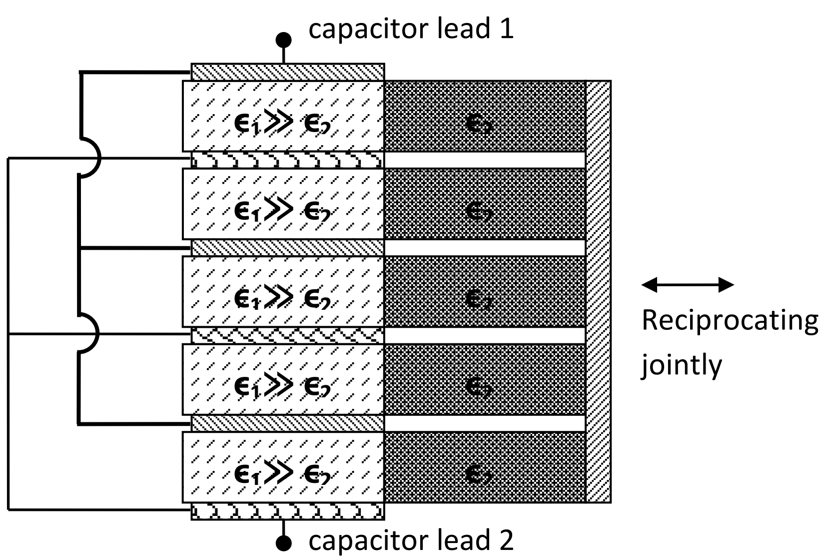
The original purpose to insert enough intermediate plates is to meet a basic condition $A \gg d_0*d_0$, but if the element capacitor's thickness d_0 is too tiny, then it will make the breakdown strength E_{max} increase many folds, and only when thicker than a threshold value, then the E_{max} seems constant.

For example, the DuPont's brand **Mylar** is just such a special: if thickness > **14mil or 356µm**, then E_{max} **= 80MV/m**, else if thickness = **0.25mil**, then E_{max} **= 800MV/m**, else the thinner, the higher.

As the max energy for a given constant volume = $Volume*\epsilon\epsilon_0 E_{max}^2/2$, so if the inserted number **N** is reasonable, then the energy capacity has nothing to do with insertion number **N**, else if too dense the energy capacity will be multiplied because E_{max} will increase if spacing very short.



a. cascade mode, total capacitance = embedded_capacitance/(**N+1**)



b. parallel mode, total capacitance = embedded_capacitance*(**N+1**)

Fig. 5: too thick capacitor's main plates inserted with many intermediates

While the count **N** of intermediate media blades are inserted, to separate dielectric blades, the same insertion count of intermediate electrode plates are also needed.

There are many tactics of wiring the inserted electrode plates, such as parallel mode, cascade mode, or mix mode.

Above **fig. 5** sketchingly teaches how to stuff thick capacitor with many very thin dielectric laminating blades, and combine all blades into a drivable comb.

It is just a sample with **N = 4** plates inserted between **2** main plates, in fact, N can be as many as necessary to assure **plate area ≫ (neighboring plate distance)^2**, as long as both economics and performance factors are considered.

When extreme high voltage is pursued, it is preferred to wire in cascade mode that nothing wiring job is required really. In this case, the whole capacitance equals the embedded cell capacitor's capacitance divided by total cell number, i.e. $\mathbf{C_{grand} = C_{cell}/N}$, the mode illustration can be seen in sub-fig. **5a: cascade mode**.

When higher current is pursued, it is preferred to wire in parallel mode that every other one electrode plate is connected together. In this case, the whole capacitance equals the embedded cell capacitor's capacitance multiplied by total cell number, i.e. $\mathbf{C_{grand} = C_{cell}*N}$, the mode illustration can be seen in sub-fig. **5b: parallel mode**.

As to the mix mode that can just be the simple mix of cascade and parallel mode, most likely it is for midrange voltage goal.

Although the deployment of tiny thickness element capacitors can increase the energy density, the mechanic strength of every individual media combination slice may be deteriorated, especially, the thinner the material, the greater intolerable deformation under stretch stress and the quicker increase of undesired friction, so careful **trade-off** should be considered.

§10. Special driving mechanism for dense insertion of intermediate plates

As to how to drag-out or push-in the combination dielectric strips or slabs or blades, it is not a scientific issue, but a technical or engineering issue.

Assuming the two dielectric media both solid, we can joint adjacently the media of same size on a common substrate strip, and then make the strip drivable, but the affect of substrate should be considered.

For **N-**plate inserted system, all parallel media-carrier strips should be joined together to a rigid lead bar, and then total driving force is distributed to dielectric pieces uniformly.

As the speed of work stroke does not matter, we can use gear system or winch or whatever fast or slow means to drive the displacement for better torque or force match. For example, the high voltage system can either be hand-powered via winch, or wind-power, or regular electric motor, or fuel engine.

For **Z**-pinch application, we wish the discharge pulse as narrow as possible, however it has no relation to the accumulation speed of high voltage. That is why multiple mechanic drive still allowed. Only for applications of high ratio of duty cycle, e.g. fusion reactor, we need speed the mechanic driving response time.

For friction reduction, all metal plates and media surface should be polished as mirrors. Some dielectric media are innately low friction, e.g. **Teflon** (Polytetrafluoroethylene), just consider it if its dielectric properties meet design requirements.

§11. What if one dielectric medium is liquid?

Solid dielectric media are never the exclusive choice, but at least one of the pair media should be solid for convenience of drive and separation of media.

When one of the media is liquid, the partner medium is better to be soaked inside to take advantage of gravity or hydraulic pressure induced automatic displacement.

Some liquid dielectric media have high breakdown strength and decent **ϵ**, e.g. transformer oil: $\epsilon = 4.5$, $E_{max} > 110MV/m$, specific weight $900Kg/m^3$, also good thermal conductivity and arc quenching ability, so just choose it if possible.

There are some special phenomena with liquid media: bubble and cavitation. It is better to avoid the occurrence because dielectric properties will be changed if too many embedded bubbles, also the cavitation is harmful and can corrode mechanic parts, despite that cavitation may induce nuclear fusion too, anyway not significant.

Not only liquid, but also gas phase can be considered if it can feature high breakdown electric field strength. Unfortunately all gas media have lower breakdown strength compared with solid and liquid.

§12. Why pulse output and how to control pulse width?

During increase of voltage, i.e. switching from high dielectric permittivity to low one, any load will be "**toxic**", because the load will draw electric current, and then depress the accruement of voltage, also cap the absorption of mechanic energy; only therein idling can maximize the energy conversion from mechanic to electric.

Thus, there should be a switch to disconnect the load from the capacitor while in action of displacement, and then reconnect during phase of "**rest stay**" aka "**step stay**" while same medium is **U**-turning or arc-sweeping inside the margin which width equals to the difference value between the medium and electrode plates, as illustrated in the fig. **6**.

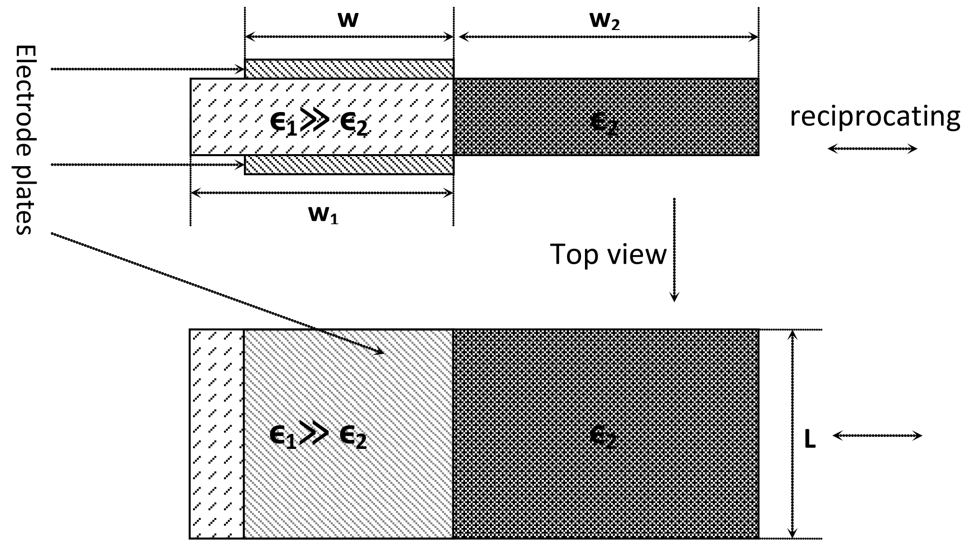
As powering load during voltage accumulation will dampen the max accessible voltage, so an application based on such component is most preferred to be used in pulse mode.

To vary the sharpness of pulse, the dielectric blade's geometry size is expected in proper configuration, as illustrated in the subject figure.

For the reciprocal model, $\mathbf{W_1 > W}$ enables excitation voltage enough time to recharge capacitor, $\mathbf{W_2 > W}$ enables output voltage enough time to power load. Such a case is showed in sub-figure **6.a**, where **W** stands for width of electrode plates, and $\mathbf{W_1}$ width of medium $\boldsymbol{\epsilon_1}$, $\mathbf{W_2}$ width of medium $\boldsymbol{\epsilon_2}$.

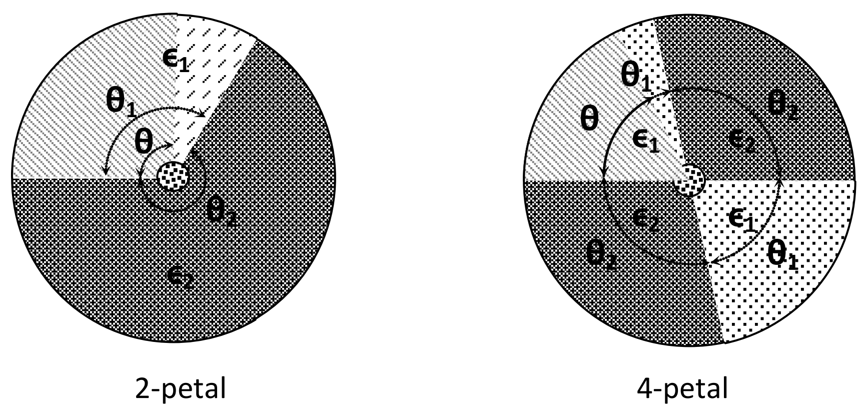
For the rotary model, $\boldsymbol{\theta_1 > \theta}$ enables excitation voltage enough time to recharge capacitor, $\boldsymbol{\theta_2 > \theta}$ enables output voltage enough time to power load. Such a case is showed in sub-figure **6.b**, where $\boldsymbol{\theta}$ stands for arc angle of electrode plates, and $\boldsymbol{\theta_1}$ arc angle of medium $\boldsymbol{\epsilon_1}$, $\mathbf{W_2}$ arc angle of medium $\boldsymbol{\epsilon_2}$.

a. reciprocating model



W_1 > W enables excitation voltage enough time to recharge capacitor,
W_2 > W enables output voltage enough time to power load.

b. rotary model



θ_1 > θ enables excitation voltage enough time to recharge capacitor,
θ_2 > θ enables output voltage enough time to power load.

Fig. 6: reasonable input or output window determined by media over-cover plates

If **$\delta W = W_i - W$**, or **$\delta\theta = \theta_i - \theta$** (**i=1** or **2**) too small, even close to zero, the rest stay width, or pulse width of recharge or discharge could be very or extreme narrow, by specially arranging the load, it is possible to simulate the explosive effect, such as **Z-**pinch setting, water explosion, etc.

Generally speaking, the specific power will be enlarged at least to **W/δW** or **θ/δθ** times, and it is guaranteed by the mechanism. For example: if **W/δW= 1000**, and engine input mechanic power **1KW**, then minimal output pulse power is **1MW**.

As the load can be arbitrary, the real pulse width can be far short than the mechanism guaranteed max width, so the above exampled conservative **1MW** could be **1GW** or more in some applications, such as **Z-**pinch.

§13. Design exercise

Assuming we need to build a **1GV** generator for particle accelerator, and selecting transformer oil with dielectric constant **ϵ** = **4.5** as primary electrostatic energy storage, the soaked ceramic with high dielectric constant **ϵ** = **22600** for the initial exciting field medium, let us try to scale the generator in **3** different energy order of magnitude.

The exciting voltage = $(\epsilon_2/\epsilon_1)*V_2$ = **(4.5/22600)*1000,000,000V = 200,000V = 200KV**.

Transformer oil can withstand **100MV/m**, so for **1GV** output, we need **d = 10m** length at least. With above given data, we calculate the energy density, and get **0.22MJ/m**^{3}.

For an ideal capacitor, the plate area **A** should be far larger than **d*d = 100** square meter. If the area is **100** times **d*d**, then **10000m**^{2} area of every single plate should be assured, of course, that is obviously an impossible monster.

To avoid above ridiculous geometry, we have to insert lots of plates inside the **10m** distance. Assuming **N = 1000** pieces of plates inserted, i.e. $d_0 = d/1000$ = **10mm** thickness for every single cascading element sub-capacitor.

For easy estimation, just assuming the plate shape is square rectangle that means equal size for all **4** sides. To meet $A \gg d_0*d_0$, e.g. reasonable $A = 25*d_0*d_0$, then we find the minimal plate size should be at least **50mm x 50mm** or **5cm x 5cm.**

For such a basic size, the minimal energy storage equals energy density multiplied by volume: **0.05m*0.05m*10m*0.22MJ/m**^{3} **= 5.5KJ = 5500J.**

The next two scaling of energy order of magnitude are **550KJ** and **55MJ** which respective plate sizes are **50cm x 50cm** and **5m x 5m**. Any of those can be reasonably housed in a big commercial building.

As to the mechanic driving force, for the basic **5cm x 5cm x 10m** capacitor column with **1000** pieces plates insertion, the total displacement force is **F = 5500J/0.05m = 110000N ≈ 11000Kg = 11 tonnes**. Every element ceramic slice will subject to **11000/1000 = 11Kg.**

Scaling to **50cm x 50cm x 10m** embodiment, we get **110 tonnes** for total, and **110Kg** for single piece; to **5m x 5m x 10m**, **1100 tonnes** for total, and **1.1 tonnes** for single piece.

The **55MJ** is about the energy amount of one kilogram gasoline, and such a system is just the next pursue of Sandia Lab with their prediction of fusion breakeven dream.

If the said equivalent **1Kg** gasoline is combusted by a car of fuel economy **10** liters per **100km**, the car can run about **10km** distance, within about **6** minutes if at **100km/h**.

For the **55MJ** jumble model, perhaps a heavy duty **diesel engine** of **300HP** (horsepower) is needed for providing the huge **1100** tonnes drive force to dielectric piston.

And maybe significant charging time between minutes and hour is needed to infuse the **1kg** gasoline equivalent energy to the huge capacitor, depending on how fast the operator expects. If imagining the aforementioned car analogue calculation, **6** minutes seems a reasonable speculation.

Also, not to worry about this long time high voltage rise time, it is not the pulse width. Only when the **HV** output is discharging to a load, it makes sense to treat discharge time as pulse width and the **100ns** to **200ns** for **Z**-pinch is desperately desired.

Total transformer oil weights are **0.05*0.05*10*900Kg = 22.5Kg**, **2250Kg**, and **225 tonnes** respectively for above **3** dimensional scaling cases. Of course, when the solid dielectric medium is fully inside capacitor, all the oil must be displaced out, so a quasi same size oil tank is needed to hold the displaced oil, and be pumped back when dielectric piston is lifted.

For all scaling models, the exciting voltage = $(\epsilon_2/\epsilon_1)*V_2$ = **200KV** is same, but exciting energy = (ϵ_1/ϵ_2)***output_energy** is different: **1.1J**, **110J**, **11KJ** respectively for **5.5KJ**,

550KJ, **55MJ**.

The equivalent capacitance in **HV** status equals: **2*rated_energy/rated_voltage**^{2}, i.e. **0.011pF, 1.1pF, 110pF** respectively for **5.5KJ**, **550KJ**, **55MJ**.

All the aforementioned **3** scaling models have same length of **10** meters, but it is too ideal because the grand total of thickness of all inserted intermediate plates is ignored.

Now, we need consider dimension correction to address above concern. Although I assume the count of the intermediate metal plates = **1000** pieces, anyway, it seems arbitrary because the purpose-oriented condition $\mathbf{A \gg d_0*d_0}$ is fuzzy and flexible, however, regarding the double of ideal length as last physical length may be a reasonable assumption.

And because it is not the metal plates but the dielectric media that bear the energy, so whatever the last correction is applied, all never affect other parameters estimation exception the embodiment total length may be significantly larger than the ideal **10m**.

Is the size too huge? Not really!

It is so pretty if compared with **Sandia Lab**'s LTD-based **1** petawatt proposed model that features a super size of **104** meters diameter and voltage less than **5.4MV,** as per the Wikipedia literature under key word Z_Pulsed_Power_Facility.

It should be more glory if compared to the **1000** meters long **1GeV** LENAC accelerator of the Spallation Neutron Source Center in Oak Ridge National Lab.

If not select transformer oil, but the advanced **AF45** special glass, we can further reduce the dimension. Because **AF45** features a super strong dielectric strength of **1.2GV/m**, so that only **1** meter long can withstand the wanted **1GV**, further, perhaps it is possible to build a desktop or benchtop electrostatic **GV**-level particle accelerator!

Even **conservatively** stick to the same with or a little bit higher than the voltage level that the prior art can achieve, there is no need of recalculation of all dimensions except electric parameters, because previous dimension calculation is based on energy density.

Assuming the said Sandia's **LTD**-based plan of **5.4MV** is to be implemented via this invention, the exciting voltage = $(\epsilon_2/\epsilon_1)*V_2$ = **(4.5/22600)*5,400,000V = 1075V**, such a low voltage can be easily realized by whatever cheap means.

Again the equivalent capacitance in **HV** status equals: **2*rated_energy/rated_voltage^2**, i.e. **0.38nF, 37.7nF, 3.8μF** respectively for **5.5KJ**, **550KJ**, **55MJ** systems.

The wiring mode of inner inserted electrode plates is no longer the pure cascading of cell capacitors, but a mix of cascading and paralleling model to reach the **5.4MV** compromised voltage.

§14. Is generator-motor double-duty possible with a device based on this invention?

Now that civil application possible, the industry will be amazed at the potentials.

It is well known that most regular magnetism-involved electric motors can be used as generator by changing the wiring, and vice versa, though the manufacturer's preset purpose either as a generator or a motor, never both.

As an analogy, the pure electric field involved generator can also be used as electric motor by minor re-configuration, and vice versa.

However, single-purposed products always have higher effect and best performance.

If well designed, dielectric displacement motor can exhibit huge torque far higher than the regular magnetic-based motors, because dielectric motor can withstand extreme high voltage pulse, not like regular motors with strict voltage rating.

The gorgeous vista includes but not limits to: excellent torque output, saving torque converter or gear reducer or transmission, smooth varying speed, easy change of rotation direction, etc.

Unfortunately, the existing industrial **3**-phase or household single phase electric power supply is never suit to the utilization of dielectric motors, because those motors can only be fed and function by high voltage pulse power supply.

Although power **MOSFET** semiconductors can be used to make the wanted super high voltage pulse and frequency varying power supply by converting the commercial hydro power, however the limitation of transistor reverse breakdown voltage is always the bottleneck as in the aforementioned analysis, so that the **MV**-level pulse power supply dooms prohibitively expensive, despite of **KV**-level cheap but weak.

So the prerequisite to promote the dielectric motor is to promote the economical dielectric piston-driven high voltage generator.

§15. Is dielectric displacement generator equal to triboelectric generator?

Although a triboelectric generator is very similar with dielectric displacement generator, the difference is still obvious: the former depends on dielectric material's capability of surface ionization caused by friction; the latter prefers charge-neutral bipolar media to reduce friction during displacement.

In a triboelectric generator, a material with high proneness of losing electrons during friction is matched with a material with high proneness of grabbing electrons, e.g. nylon-polyvinylchloride pair.

In a dielectric displacement generator, the significant deviation of dielectric constants between two media is most interested. The friction between electrode plates and dielectric combination is expected as low as possible.

§16. Conclusion and the profound influence to future technology

In general, when dielectric medium in capacitor is switched from high permittivity $\boldsymbol{\epsilon_1}$ to low one $\boldsymbol{\epsilon_2}$, such a displacement needs input of mechanic energy, and in turn this mechanic energy will be converted to electrostatic energy, thus voltage will be multiplied greatly by $\boldsymbol{\epsilon_1/\epsilon_2 \gg 1}$**,** though no charging current is infused to capacitor.

As no limit is imposed on $\boldsymbol{\epsilon_1/\epsilon_2}$ and many stages amplification is allowed, so there is no limit for the possible high voltage output, provided no breakdown occurs inside all dielectric media.

By employing new generation of dielectric materials with extreme high breakdown strength, plus providing as ample as needed space, **GV** level is not hard to reach, in contrast, with the prior art, even the record high voltage is merely under **50MV.**

With such a breakthrough invention, a virgin hi-tech domain is looming large, enabling countless potentialities that may subvert traditional or stereotype design and engineering practice in many aspects, as well as many industries including the edged ones will be created or boosted, hence ultimately promote the globe economics.

Academically a new theory should be created to cover this blank background science of all here inventions, now, I name it "**dielectrodynamics**", and will systematically write a textbook about it in near future.

At last, let's present some potential applications.

§17. Application in high energy physics Z-pinch experiment

Fig. **7** shows a typical **55MJ 1GV** multistage single shot high voltage generator.

A powerful engine, e.g. **300HP** diesel engine, provides the system all energy. It drives a heavy duty gear transmission or winch.

There are some sturdy sky rails used as gantry crane. Many pulleys are mounted on the rails and on the huge dielectric blades assembly. Steel ropes are crossing pulleys in force saving mode, then hooked to the said transmission or winch.

The dielectric blades can be made of dielectric media combination of ceramic piezoelectric material with high dielectric constant ϵ_1 and transformer oil ϵ_2 with high breakdown strength, e.g. $\epsilon_1 = 22600, \epsilon_2 = 4.5, \epsilon_1 / \epsilon_2 = 5000$.

For a detail calculation of parameters, please check the **§13** "Design exercise".

Because transformer oil is fluid, displacement can be done by gravitation or atmosphere pressure or pump depending on how fast demand, and an oil tank is deployed beside the dielectric blades module.

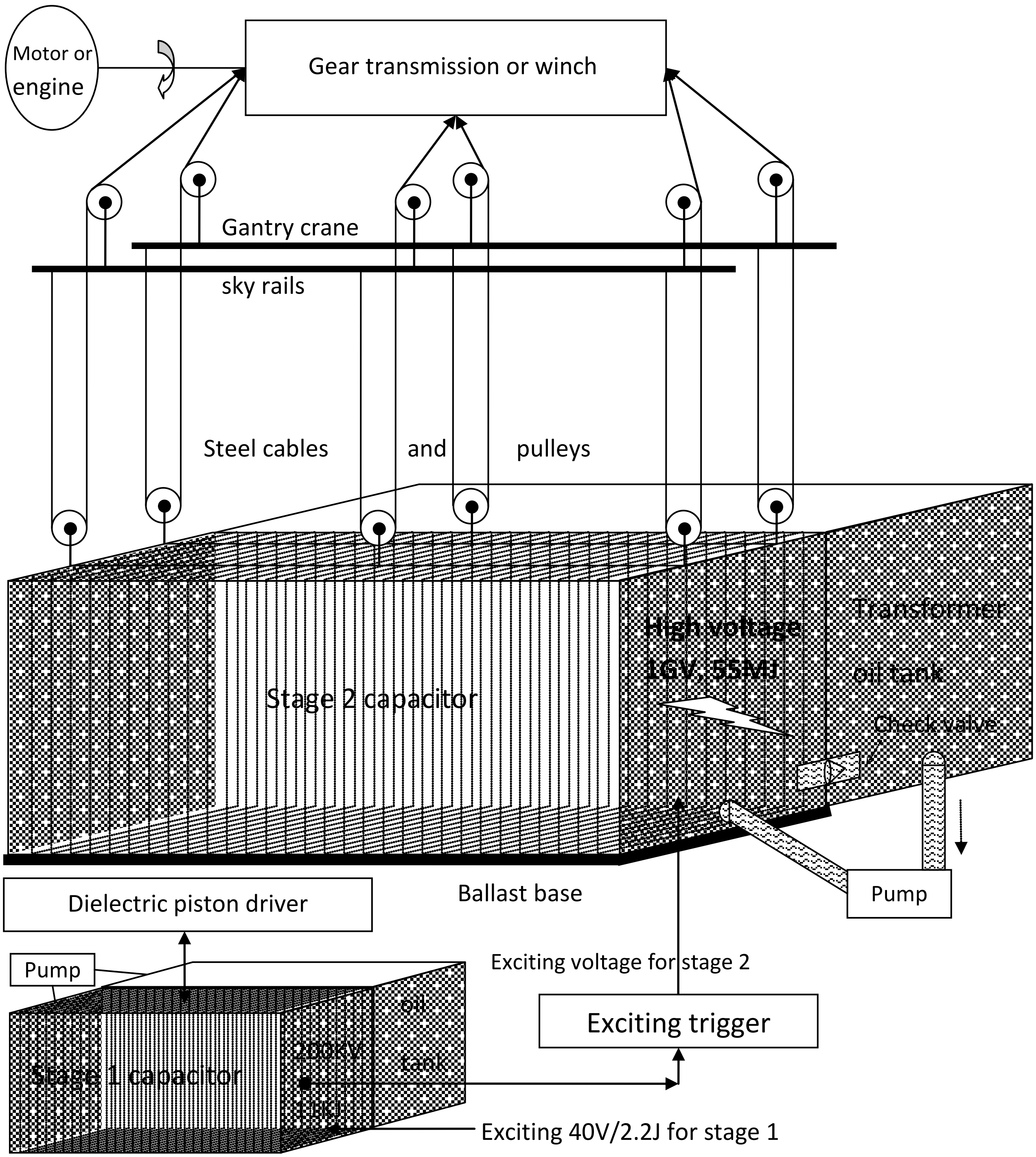


Fig. 7: typical model 55MJ 1GV multi-staged high voltage generator

When the said $\boldsymbol{\epsilon_1}$ is completely inside the capacitor, the oil is displaced to the tank via the check valve, as well as when the dielectric blades module is lift by the crane, the oil will flow back and be pumped to the capacitor.

Without check valve and pump, the stage **1** excitation module can be completely immersed in oil basin, as the volume is far less than the stage **2** module.

As hundreds tones force involved in stage **2** module, the base should be well blasted.

The typical size for such a performance could be **5** meters both wide and height, and **10** to **20** meters long depending on how density the intermediate electrode plates inserted.

§18. Application in general high voltage periodic pulse generator

When a pulse power supply is customized for a constant load, it is relatively easy because input and output can be well matched at design stage.

But for universal periodic shots pulse power supply, things are getting complicated, because the loads are changeable time by time or shot by shot, and the ready manufactured machine may not be flexible enough to cope with all different loads.

Unmatched application is usually very low efficient and even risks of damage or large energy waste, just analogous to bombard a mosquito by flak cannon.

Hereby I present an adaptive pulse power supply driven by a reciprocal engine or motor as power source, and in fact, a rotary engine will be indirectly workable too, just by simple rotary to reciprocal conversion mechanism, though undrawn in **fig. 8**.

As manifested in section **§12**, for a sustainable operation, the generated voltage output of dielectric blades displacement transformer should be consumed in time, otherwise it will block next cycle or result in electric breakdown, so that suspension of load, i.e. idling, is not allowed.

If the load only consumes a small percentage of total pulse energy, then the leftover energy should be dumped somewhere, or fed back to input.

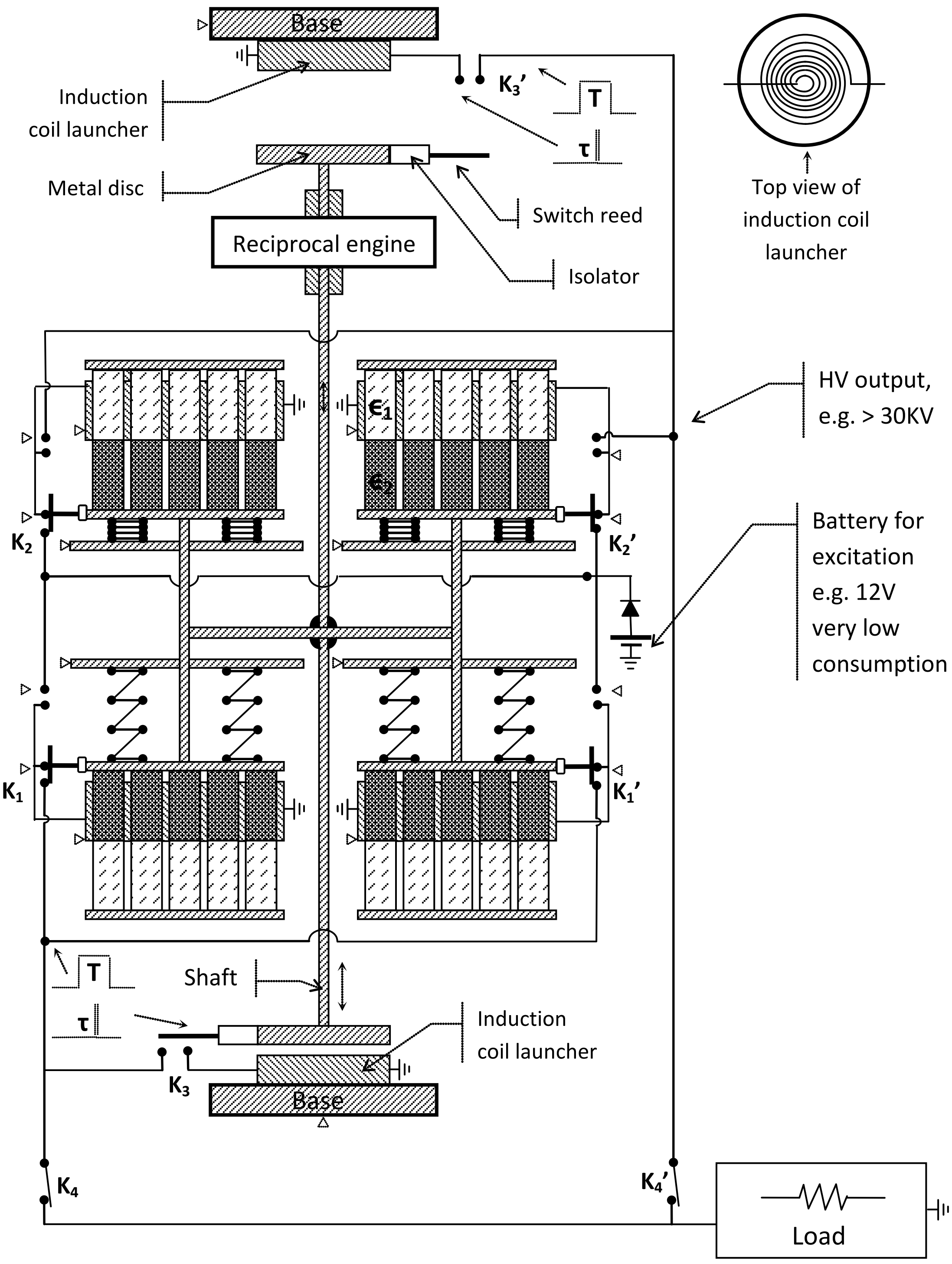


Fig. 8: high voltage periodic pulse power supply

Feedback of unused energy to input is good idea to conserve energy. The duplex design in **fig. 8** just follows this good practice. The drive shaft runs through the engine block, so as to feedback remnant energy from opposite ends.

Because the electrode size is always shorter somewhat than the dielectric blades, so that either medium $\boldsymbol{\epsilon_1}$ or $\boldsymbol{\epsilon_2}$ can monopolize the capacitor for a small hesitation time **T** during a short reciprocal trip.

As a simple timing means, **2** simple position sensing switches $\mathbf{K_3}$ and $\mathbf{K_3'}$ are attached to the induction coil launchers. However, the delay time $\boldsymbol{\tau}$ can only be **T/2**, and the pulse energy is supposed to be consumed within **T/2** after any duet of dielectric blades triggered respective position switch**.**

When one dielectric medium is fully displaced out from capacitor, i.e. either switch pair $\mathbf{K_1}$ $\mathbf{K_1'}$ or $\mathbf{K_2}$ $\mathbf{K_2'}$ just turn-on, the timing is beginning, then after $\boldsymbol{\tau}$ lapsed, automatically turn on the respective timing switches to energize the respective induction launcher with remnant energy to assist the engine.

While one pair capacitor ready to output pulse, simultaneously the other pair capacitor will begin to be recharged by an excitation battery.

The status of load switches $\mathbf{K_4}$ $\mathbf{K_4'}$ can be arbitrary so as to feature the load adaptive performance. When turn off, the machine is totally idling, otherwise either light load, partially idling or full heavy load.

Someone may wonder why to use a quartet of dielectric blades, it is because that symmetrical structure claims best mechanic stability. In fact, it is also workable even reducing to duet structure, as there is full redundancy in the quartet design.

For constant load application, simplification is possible by omitting the remnant feedback sub-system, i.e. removing the induction coil launchers and associated parts.

§19. Application in utility grade dielectric motor

A simple dielectric displacement motor can be construed as a reciprocal duplex model showed in fig. **9**, though it is only good for fixed load.

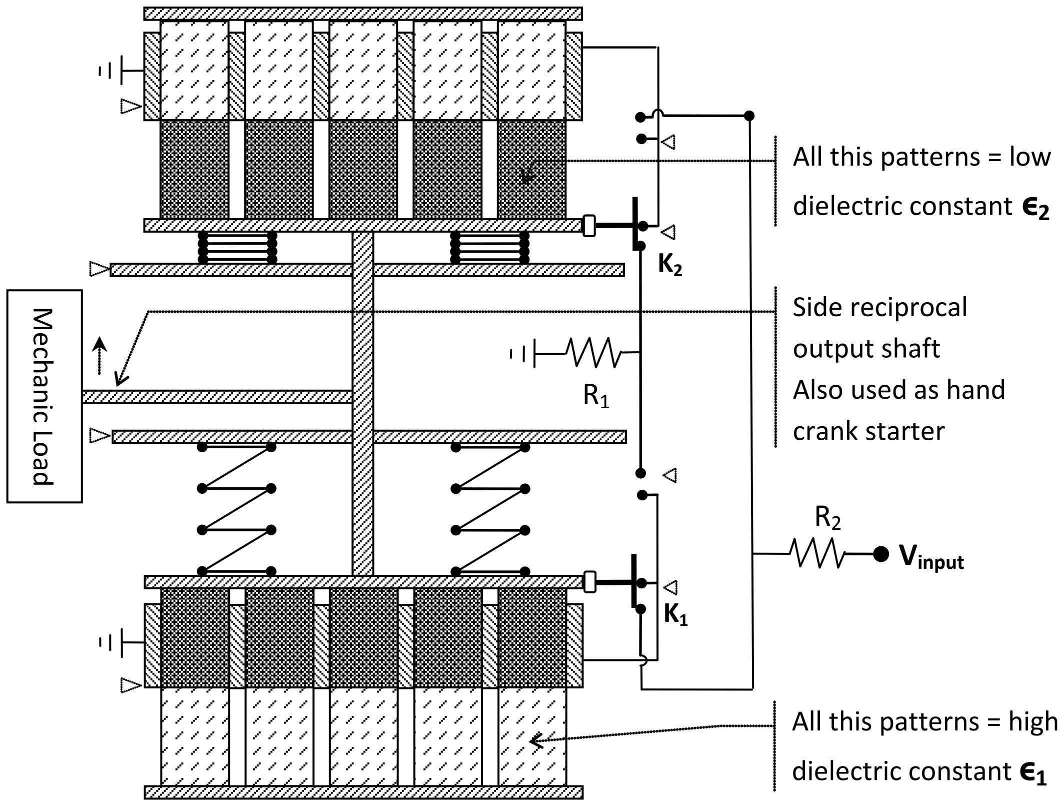


Fig. 9: typical duplex reciprocal dielectric motor for fixed load

It comprises basic dielectric media pair, main electrode plates, the inserted electrode plates that can be wired to main plates via cascade or parallel mode, springs, shaft, resistors that limit discharge current or recharge current, and switches.

The **5** pieces of dielectric blades combination is only for graphing convenience, in fact, the real count can be as many as needed in dependence of embodied design. This statement applies to all figures.

As springs are in tension because of over-stretched apart from equilibrium, as well as dielectric piston tends to be accelerated because the lower dielectric constant medium is going to be displaced by the higher one.

At moment of piston approaching dead point, one end position switch connects power supply with input terminal of capacitor module, and then electrostatic energy is stored.

The grounding sign in the figure is at least the “**virtual grounding**” that only means all the same marked terminals are linked together electrically for graphing convenience, in some cases, real grounding to earth maybe necessary if otherwise specified, but not always necessary or allowed.

If full loaded, then the remnant voltage after mechanic work output during $\epsilon 2 \rightarrow \epsilon 1$ is $(\epsilon_2/\epsilon_1)V_{in}$ far less than V_{in} because $\epsilon_1 > \epsilon_2$, hence good efficiency, else if idling, then the remnant $(\epsilon_2/\epsilon_1)^{0.5}V_{in} > (\epsilon_2/\epsilon_1)V_{in}$. So if using this design to power variable load or under-rated light load, the efficiency will be very low, because most energy is dissipated in the discharge resistor R_1 then bad heat will be generated.

§20. Application in mobile medical X-ray source

Portable **X**-ray source is highly desired in many applications, such as battlefield wound diagnosis, non-destructive detection, crystallography etc.

Conventional X-ray sources are so cumbersome that stimulates industry to try the downsizing of weight and dimension for the mobile applications.

In principle, X-ray is generated by the bremsstrahlung (braking) effect of high kinetic electrons, and the normal photon energy is almost half of the electron peak energy.

In recent years, triboelectricity is considered for this application. Unfortunately it is physically unable to accelerate electron to a decent high energy that is reachable by in-house X-ray equipment with usual photon energy **150KeV**, but mere humble energy up to **50KeV**, hence the application scope is seriously restrained to a niche market.

The action of peeling tape can also produce electrostatic high voltage and weak X-ray on similar level with previous method. In fact, it is based on triboelectrics too, only by stick-slip friction instead of rubbing.

Such situation motivates further research on how to create decent high voltage for mobile application by whatever accessible non-electric power source in situ.

There are multiple choices for operation power where electric power inaccessible except battery in situ, such as manpower or with hydraulic hand tools, firecracker etc.

Fig. 10 is a hand-pump hydraulic powered mobile X-ray generator.

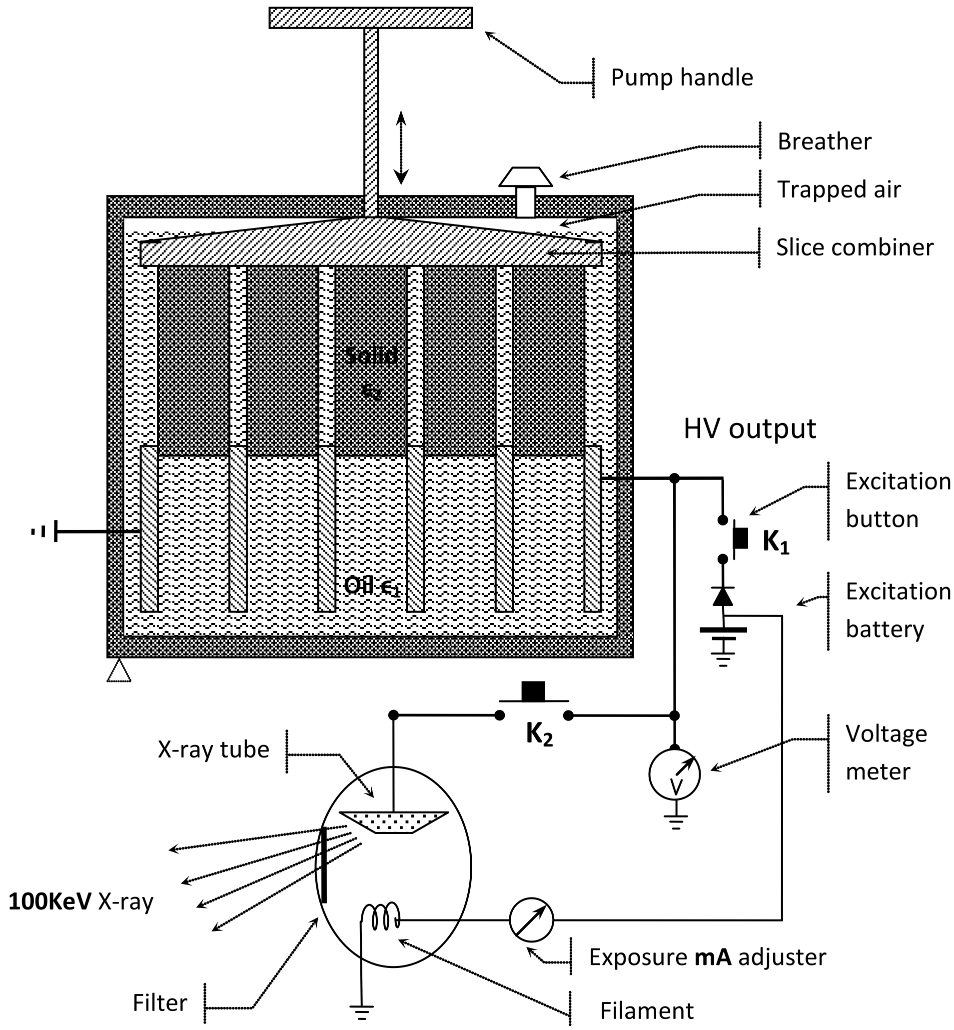


Fig. 10: simple hand pumped hydraulic mobile pulse X-ray source

The output peak voltage **KVp** can be controlled by hand pumping as while watching the voltage meter indication.

The exposure **mA** parameter is adjusted by changing the filament current so as to regulate the emission amount of active electrons.

As to the exposure time, it is determined by the capacitor's total stored energy, hence not easy adjustable, but in fact, there is no significant impact, because modern digital radiography only need very short exposure time and is not picky to it.

Usually a few milliseconds good enough, and it is easy to meet by optimizing the pairing of capacitance and the equivalent resistance of X-ray tube.

The initial electrostatic field excitation is manually done by turning on button $\mathbf{K_1}$ for a moment, then it is time to start cranking pump until the wanted high voltage obtained, and then click button $\mathbf{K_2}$ to flash X-ray. Obviously the battery is consumed slightly, so even cheap regular **AA** size **1.5V** dry cell bank is competent.

Usually a chest posterior anterior X-ray digital image will impose about **0.25mGy** dose radiation for adult patient, so it means even **1J** produced X-ray energy is too enough.

According the radiation theory, the X-ray production efficiency equals $\mathbf{(7*Z*KVp*10^{-5})\%}$, here **Z** = anode atom number.

For the regular tungsten anode, **Z = 74**, so if **KVp = 100KV**, then the efficiency is about **0.5%,** it means that only a fractional energy is converted into X-ray, and most energy is dissipated as heat, so that **200J** total input energy is probably enough for once imaging.

Even a lady's weak hand can easily and quickly and reliably input **200J** to this mobile device by exerting dozens of pump strokes, and the number of strokes depends on the dielectric media setting.

For example, given the dielectric pair of Mylar and IPPP fire-proof hydraulic oil, then we have $\mathbf{\epsilon_1 = 6.75}$, $\mathbf{\epsilon_2 = 3.2}$, ratio $\mathbf{\epsilon_1/\epsilon_2 = 2.11}$, excitation $\mathbf{V_1 = 12V}$**,** the wanted $\mathbf{V_2 = 200KV}$.

Solving this equation:

$\mathbf{12*(2.11)^{(n+1)/2} = 200000}$,

results in solution of stroke sequence number **n = {2*log(200000/12)/log2.11} -1 = 25.**

Of course, by increasing ratio of $\mathbf{\epsilon_1/\epsilon_2}$, the required crank times **n** can be further reduced, but enough muscle should be exercised, as there is no change of the total **200J** input.

§21. Application in new type propeller of ornithopter aircraft

The aerial propellers in my inventions can mechanically either be the umbrella-like or planar shape (synonymous designations include board propeller, panel propeller).

The propulsion force usually comes from a short time acting powerful energy release, such as pulse electromagnetic energy discharge, or explosion driven mechanic thrust.

Dielectric high voltage generators can accumulate the absorbed energy to produce a high power electric pulse, and such a property can be employed to propel an aerial vehicle via special propeller.

Just like the webs of duck feet or bird wings, human beings have struggled for many centuries to experiment flapping-wing aircrafts, or ornithopters that can vertically takeoff, but still failed to commercialize it.

Once upon commercialization of ornithopters, humankind will benefit in many aspects, e.g. affordable personal aerial commuting, remote internet service, goods shipping, etc.

By discharging high voltage in capacitors to a base-fixed disc-shape coil that contacts with a metal disc, such as aluminum disc, the huge current in the coil will induce a very strong magnetic field, and the induced eddy current in the metal disc will generate a matchable repelling magnetic field, so as to launch the metal disc in very high velocity.

For example, for a **10KV** voltage charged capacitor with **2.2KJ**, experiments show that the pulse discharge can accelerate a **4** ounces projectile to about **160m/s** initial speed**,** or if driving a realistic aerial vehicle of gross weight **200kg**, it may theoretically lift about **2200/(200*9.8) = 1.12m** for a single pulse discharge.

I propose the umbrella-like propeller that can perfectly fit the high voltage power supply comprising dielectric blades displacement module, as is in fig. **11.**

According to aerodynamics, for **50m/s** typhoon wind speed, the pressure of facing surface can reach about **150kg/m^2**, and is roughly proportional to the square of wind speed. That means **1** square meter umbrella with high enough speed of treading air may levitate a regular adult plus reasonable weight of driving module.

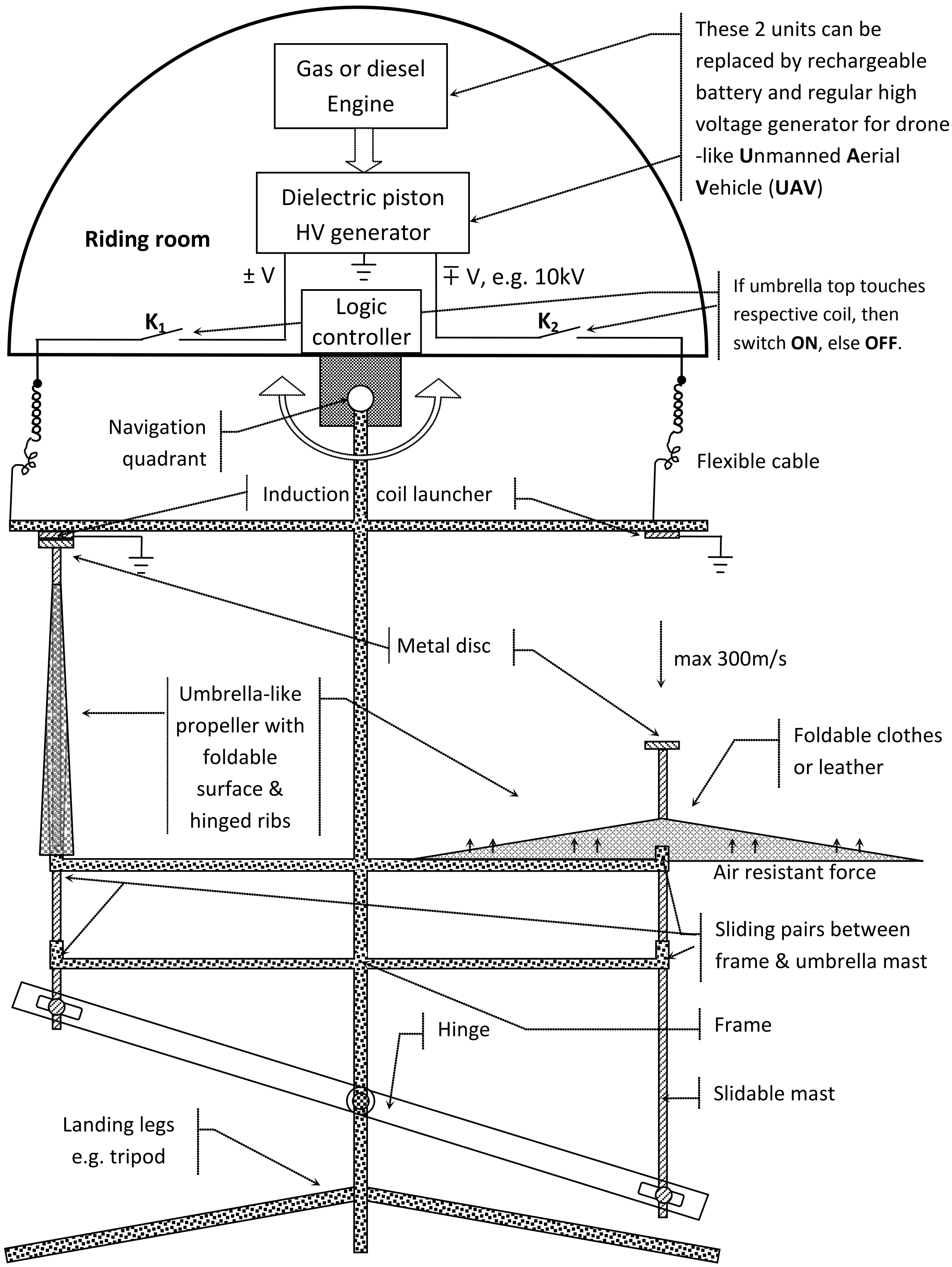


Fig. 11: duplex umbrella-like propeller for aerial lifter or ornithopter

The higher the initial speed of umbrella, the stronger the propelling force, so by optimization of design, a proper umbrella area can be determined.

After umbrella full is unfolded then aircraft is pushed some distance, it should return to the folding status for next propulsion. In the illustrated duplex design, at any transience, one umbrella is unfolding and another is folding.

In simplex design, i.e. only one umbrella system, folding umbrella can be simpler, even needless of extra energy input, as luckily the moving vehicle itself can help to retract the umbrella, i.e. fold it, however small driving power can enhance reliability.

For heavy duty, such as aerial lifter or passenger ornithopter, the power source can be a regular gas or diesel engine, and the engine usually drives a rotary dielectric replacement high voltage generator.

For light duty, such as drone-like unmanned aerial vehicle, those **2** units can also be replaced by rechargeable battery and regular high voltage generator.

The engine can also drive a hydraulic pump first, and then let the hydraulic system drive a reciprocal dielectric replacement voltage generator via a dual-action hydraulic cylinder.

When the top disc of umbrella touches the launcher coil, the respective switch $\mathbf{K_1}$ or $\mathbf{K_2}$ is turned on, high voltage discharge occurs, the umbrella pushes air fiercely, hence propelling force accelerates vehicle in opposite direction of fanned air.

The whole propeller module is hinged to base of riding room, and navigation can be at least done by swinging the propeller. If only for home based aerial lifter application, then horizontal navigation is no longer needed or just a simplest design.

To have more payloads, all parts, including landing legs, the respective material and size should be well balanced.

Almost all engines in market are the type of rotary, however if the type of reciprocal fuel engine is accessible, though not good pulse power, it may still be possible to directly drive the umbrella, just with a large degradation of linear velocity because piston's speed of most internal combustion engines is usually at max about **20m/s** which is far inferior to the pulse jerk propelled by electromagnetic catapult, but increasing area of umbrella can offset the degradation, and in turn, increase of volume and gross weight.

Postscript:

More detail specification regarding all above discussed applications is disclosed in my patent application USPTO 15/267,122:

Dielectric blade comb piston unlimited voltage generator, fusor and more

Many other applications have not been presented here, because this small paper can not accommodate so many contents. Anyway, I am considering writing a monograph or textbook on this new theory and applications of dielectrodynamics.

Perhaps in the near future, it will be the time of saying bye-bye to Marx generator, rare earth magnetic materials, not affordable personal airplanes, mile-size high energy particle accelerator, country-size neutron spallation system and more, just cheerfully to embrace the epoch of powerful inexhaustible fusion energy, convenient personal ornithopter and other cheap yet useful magnetic-free dielectrodynamic utilities.

§22. Reference literature

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