

## Discrete Power Converter (DPC) as hydro-mechanical model of relaxation oscillator for educational purpose.

Alexander Kornich – Principal Developer of DPC

There is another useful application of DPC mechanism <http://dpc-renewable-energy.com/> that makes sense to consider more in detail. We are talking about the similarities between hydraulic and electrical processes, which has long been known and used in the design (for example, when modeling processes and devices) and for educational purposes (for example, for illustrative purposes, the explanation of electrical phenomena).

“...The *electronic–hydraulic analogy* (derisively referred to as the *drain-pipe theory* by Oliver Lodge) is the most widely used analogy for “*electron fluid*” in a metal conductor. Since *electric current* is invisible and the processes at play *in electronics* are often difficult to demonstrate, the various *electronic components* are represented by *hydraulic equivalents*. Electricity (as well as *heat*) was originally understood to be a kind of *fluid*, and the names of certain electric quantities (such as *current*) are derived from *hydraulic equivalents*. As with all analogies, it demands an intuitive and competent understanding of the baseline *paradigms* (electronics and hydraulics). ...”

There is no unique *paradigm* for establishing this analogy. Two *paradigms* can be used to introduce the concept to students:

- Version with *pressure* induced by *gravity*. Large tanks of water are held up high, or are filled to differing water levels, and the potential energy of the water *head* is the *pressure* source. This is reminiscent of electrical diagrams with an up arrow pointing to +V, grounded pins that otherwise are not shown connecting to anything, and so on. This has the advantage of associating *electric potential* with *gravitational potential*.
- Completely enclosed version with pumps providing pressure only; no gravity. This is reminiscent of a circuit diagram with a voltage source shown and the wires actually completing a circuit. This paradigm is further discussed below.

Other paradigms highlight the similarities between equations governing the *flow of fluid* and the *flow of charge*.

In electronic-hydraulic analogy the *current* represents of *flow* and *electric potential* (or *voltage*) represents the hydraulic *head*. ...” [1].

However in the case of DPC as subject of *electronic–hydraulic analogy* we can consider not only similarity of *hydraulic* equivalents of some *electronic components* (as resistor, capacitor, etc) but even clear similarity between principal of operation such hydraulic-mechanical machine (as DPC itself) and electronic device such as Astable Multivibrator (AMV) which represents class of oscillators/generators [2].

Moreover it is becoming evident that similar principal of operation ( oscillating mode) can be explained as result of action of feedback [3] which has electrical nature for AMV and mechanical nature for DPC.

Thus DPC can be classified as self-regulating mechanism (powered by gravity force of flowing mass – water, for example) which is operating in periodical two-stage mode and represents a hydraulic equivalent of electronic device (as *relaxation oscillator*) with feedback control loop in the electrical schematic.

In a sense, one can speak about a paradigm shift as “... transition from one paradigm to another ...” [5] in the hydro-electrical analogy which corresponds the transition from equivalent terms and concepts (such as “... electric potential and gravitational potential; similarities between equations governing the flow of fluid and the flow of charge ...” [1] to equivalents of the physical structure and principles of operation (mode) of mechanism (and electronic device accordingly) based on the action of the feedback of different physical nature, but ultimately have been realized as analogy of mode of the relaxation oscillator (electronic and hydro-mechanical).

It makes sense to consider this important issue in more details by analyzing the kinematic scheme of the DPC (a) and the electrical circuit of AMV (b) on Fig. 1.

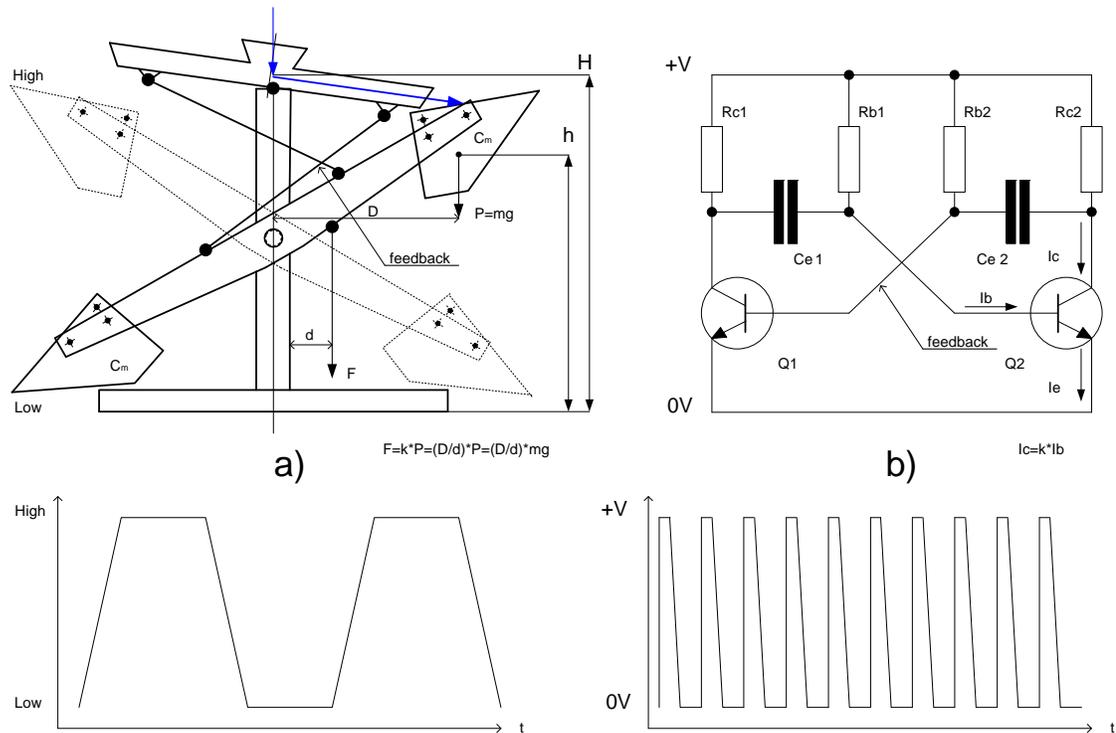


Fig.1

Firstly, we can define similarity AMV and DPC in the terms of classical paradigm of hydraulic analogy:

1. The potential nature source of power for AMV (as voltage of electrical power supply i.e. the difference between  $+V$  and  $0V$  on b) of Fig.1 and for DPC (as **hydraulic head** i.e. the difference between “High” position and “Low” position on a) of Fig.1).

2. The equivalent of electrical current (as flow of electrical charges) which goes through electrical structure of AMV from +V (high potential) to 0V (low potential) of power supply (in circuitry, +V > resistor Rc1 > transistor Q1 > ground) and hydraulic *volume flow rate* (as flow of water, for example) which goes through DPC machine (intake > feeding pipe > bucket > working stroke > ground) from “High” position to “Low” position. It is important to note that these “currents” caused by fields of potential nature: electrical and gravitational.
3. The equivalent of electric charges (and “capacitors” accordingly) which are accumulated alternately in the electrical capacitors (Ce1,Ce2) in the process of operation of AMV and quantity of water (volume) which is accumulated (also alternately) in the buckets (Cm1, Cm2) in the process of operation of DPC. It is important to note that these “capacitors” are “discharged” to “ground point” – zero potential in both cases.
4. The equivalent of conducting wires and resistors for connecting parts and components in the circuitry of AMV and structure of DPC (like pipes and constrictions in it) accordingly. It is important to note that these “resistance” caused the losses of power during of operating in both devices – electrical (AMV) and hydro-mechanical (DPC).

On this list the similar features (equivalence) of classical paradigm of hydraulic analogy have been completed because the specific behavior of DPC (as physical principal of operation of relaxation oscillator) can not be described and explained on this base.

Secondary we have to define similarity AMV and DPC in the terms of new paradigm of hydraulic analogy:

1. Symmetrical physical structure of electronic device (AMV) and mechanical machine (DPC).

We can see it clearly from similarity electrical schematic of AMV and kinematic scheme of DPC: two symmetrical combinations (left and right “shoulder”) of resistors, capacitor and transistor (for AMV); and similarly - two symmetrical combination of rocking levers (feeding upper pipe and working lower beam) and buckets (for DPC).

2. The equivalence of two symmetrical power amplifiers in the physical structure of AMV and DPC

Accordingly: transistors (Q1, Q2 for AMV) which amplify the collector current ( $I_c$ ) proportionally to base current ( $I_b$ ), such as  $I_c = k \cdot I_b$ ; and levers (for DPC) which amplify the gravity force ( $P = mg$ ) of mass ( $m$ ) – (of water, for example) accumulated in the bucket. The gravity force is multiplied (amplified) in accordance to law of lever depending on geometry of DPC machine (length of lever); and points of applying gravity force and mechanical load. In general case the gravity force can be amplified as  $F = k \cdot P = (D/d) \cdot P = (D/d) \cdot mg$ .

It is important to note that ability of DPC to amplify of gravity force is the fundamental distinct feature of innovative hydro-mechanical machine.

3. The equivalence of two symmetrical feedback crosses type in the physical structure of AMV and DPC

Accordingly: for AMV the connecting (wiring) of output of transistor Q1 (through capacitor Ce1) with input of transistor Q2 and conversely – the connecting (wiring) of output of transistor Q2 (through capacitor Ce2) with input of transistor Q1; for DPC the connecting (by rod or chain) the “right shoulder” of working beam (low rocking lever) with “left shoulder” of feeding pipe (top rocking lever) and conversely - the connecting (by rod or chain) the “left shoulder” of working beam (low rocking lever) with “right shoulder” of feeding pipe (top rocking lever).

It is important to note that applying of two symmetrical mechanical feedback crosses type in the construction of DPC is fundamental innovation step which provides the transfer some part of mechanical power from functional “output” of mechanism (low rocking lever) to functional “input” of mechanism.

This part of power is used for changing the direction (in terms of accumulating buckets) of transfer of input power (as flow of working medium – water, for example).

Therefore it provides mechanical “switching effect” in DPC (as electrical switching effect in electronic circuitry of AMV, for example). Because of the alternate nature this switching effect in the time and in the space (as result of symmetrical structure of mechanism) simultaneously the mode of relaxation oscillator [4] can be realized in the DPC operation (at least until a *flow of input working medium* is applied).

In other words we can define DPC as absolute adequate hydro-mechanical model of *relaxation oscillator* based on the action of mechanical feedback crosses type. This definition may be considered also as some new contribution in the *paradigm* [5] of hydraulic analogy [1].

Any way, we can see now that not only “... the various electronic components are represented by hydraulic equivalents ...” but even typical electrical oscillators may be represented by DPC “... Since electric current is invisible and the processes at play in electronics are often difficult to demonstrate. “[1].

The possibility to demonstrate by DPC the operation of relaxation oscillator is evident cognitive value in the process of education of students.

4. The similarity (equivalence) of two-stage time operating mode which consist of two specific intervals of time in the each period of oscillation:

The first (more longer) can be specify as time ( $t_a$ ) of accumulation of working medium in the capacitance element of physical structure (electrical capacitor for AMV or geometrical volume of bucket for DPC); the second (more shorter) can be specify as time ( $t_s$ ) of discharge (or switching) during which the working medium is released (or emptied) from capacitance.

In the terms of energy during interval of time ( $t_a$ ) the system is being in the state of potential energy mostly (excluding some leakage as the losses in the system); during interval of time ( $t_s$ ) the potential energy of system converts in the kinetic form of energy immediately.

At this time ( $t_s$ ) the useful work can be done by structure relatively to some load (electrical – for AMV and mechanical – for DPC, accordingly) and this time determines also the value of “pulse of output power” in the structure.

Interval of time ( $t_a$ ) in both cases is defined by generalized formula

$$(t_a) = R_a \cdot C_a$$

where  $R_a$  - generalized resistance (electrically or hydraulically),  
 $C_a$  - generalized capacitance (electrical or geometrical volume)

It is evident that  $T = (t_a) + (t_s)$  - period of oscillation mode in the structure (both AMV and DPC)

Because of  $(t_a) > (t_s)$  the value  $T$  is defined mostly by value of capacitance  $C_a$  for both cases.

Again, the evidence of electrical-hydro analogue between AMV and DPC even in the dynamic mode (like oscillating process) is proven by similarity the math model for both cases.

5. The similarity (equivalence) of the splitting (distribution) of input flow of working medium (in spite of different physical nature (flow of electrons and flow of water, for example))

There are two equal output flows (with evidence that flows are running from the state with higher energetic potential to the state with low, actually – zero potential). It is evident also that this splitting is performing automatically (feedback action!) and alternately through two symmetrical parts of physical structure of AMV and DPC.

The flow of electrons (electrical current) for AMV is going from high electrical potential (+V) of power supply to zero (“ground”) potential (0V) through “open state” of transistor at the moment (Q1 for example), then the current will be switched through another transistor (Q2).

Similarly, the input flow of water in DPC structure is flowing from “high” position (high gravity potential) through feeding pipe to bucket ( $C_{m1}$ , for example), and then it is delivering by working stroke to ground (zero gravity potential).

This process will be repeated automatically (after switching the position of the feeding pipe) for opposite bucket ( $C_{m2}$ , for example).

It is important to note that in both case (AMV and DPC) the reason which caused the moving of working medium (electrical current or flow of water) has the similar physical nature – potential field (electrical or gravitational).

Specifically, in the case of DPC it is possible for practical usage that splitting of input flow (water particularly): in irrigation, water distribution system, etc.

6. DPC as model of alternative source of Renewable Energy applications.

However the fundamental distinctive feature of DPC as mechanical relaxation oscillator is the fact of possibility of usage the different working mediums (not only water) for powering this machine in oscillating mode by gravity force.

DPC invention has become the result of shrewd foresight of scientist in the field of hydropower, which was formulated even a hundred years ago:

“ ... Mechanically, energy is exertion of force through space. As result this impressed force produces the motion of working medium in the space. If some mechanism being in contact (collides) with working medium is getting its own motion and is becoming the prime mover. In this way the transformation of energy can be performed up to various useful mechanical loads. Obviously, in hydro power we are dealing with gravity force and water as working medium, however other flowing masses (as sand, gravel, slurry and grain, etc) may be considered as working medium forced by gravity to input of new original prime movers. ...” [6]

DANIEL W. MEAD; WATER POWER ENGINEERING THE THEORY, INVESTIGATION AND DEVELOPMENT; NEW YORK McGRAW-HILL BOOK Co. 1915

Thus the DPC can be considered actually as prime mechanical mover which is operating as relaxation oscillator and could be powered by gravity force of various flow-free working medium. In this role DPC may be presented as additional tool in the arsenal of Renewable Energy (for tidal application, for example, etc).

#### Summary

As result of analyzing of Discrete Power Converter (*DPC* or *Kornich machine*) it was shown that structure and operating mode of mechanism represents absolutely clear and adequate the mechanical model of electrical relaxation oscillator (Astable Multivibrator or AMV, for example). This fact is significant contribution in the concept of Hydro analogue (and may be considered even as new *paradigm* in it).

The cognitive value of this fact is the possibility to provide the “visualization” of dynamical electrical processes in AMV by analogue mechanical processes in DPC.

It may be used as solid base for development and design of “DPC Educational Kit” for increasing of efficiency of education in the schools, technical colleges and Universities.

Such Educational Kit may consist of small working physical model of DPC and CD with complete technical documentation.

More detailed technical information about DPC is available on Web site

<http://dpc-renewable-energy.com/>

the working model of DPC can be found on

<https://www.youtube.com/watch?v=8W5SY651wxg&feature=youtu.be>

[1] [http://en.wikipedia.org/wiki/Hydraulic\\_analogy](http://en.wikipedia.org/wiki/Hydraulic_analogy)

[2] <http://en.wikipedia.org/wiki/Multivibrator>

[3] <http://en.wikipedia.org/wiki/Feedback>

[4] [http://en.wikipedia.org/wiki/Relaxation\\_oscillator](http://en.wikipedia.org/wiki/Relaxation_oscillator)

[5] <http://en.wikipedia.org/wiki/Paradigm>

[6] DANIEL W. MEAD; WATER POWER ENGINEERING THE THEORY, INVESTIGATION AND DEVELOPMENT; NEW YORK McGRAW-HILL BOOK Co. 1915

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