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# Perspective algorithms for the effective use of electro-osmosis for automatic installations

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**Abstract**. The paper gives the evaluation research of performance potential of using the energy of ground aquifers for the power generation used for autonomous power consumer auxiliaries. The research to evaluate the performance potential of power generation from aquifers having the exact colloidal properties of the membrane dispersed phase and filtration ground properties was done.

## 1. Introduction

The combination of electrokinetic phenomena includes: electro-osmosis, electrophoresis, osmo-electromotive force (emf) and phoro-electromotive force (pemf). These phenomena were discovered at the beginning of the 19th century and they have been studied up to now.

The nature of electrokinetic phenomena is that in dispersed materials of dielectric property at the interface of a hard dispersion dielectric-water a double electric layer occurs. The reason of its occurrence is polyunsaturated bonds on the surface of the fractured dielectric which attract water molecules from the external environment. As it is known, dipole water molecules are lined up in such a way that they are attracted by similar poles to the dielectric surface (dispersed particle). Thus electrocharged layers occurred in water along the interface having positive and negative charges in turn (a double electric layer). Very often the thickness of a double electric layer is maximum of 3-5 water molecule diameter. With putting the external electric field on the system, a double electric layer starts to move carrying the water around. Thus the water mass transfer in a fixed porous "membrane" takes place. This phenomenon of creating a hydraulic pressure head caused by the electric field is known as electro-osmosis.

## 2. Aim and tasks

It is found that the phenomenon conversed the electro-osmosis could create the electric field under the action of the hydraulic pressure head and this phenomenon is known as a stream function.

In light of physics traditions, it would be well to call this phenomenon as osmo-emf. This category also includes such phenomena as electrophoresis and phoro-emf.

Due to the fact that almost in all dispersed naturally occurring materials the dispersed rock materials are present as a dispersed phase, and as a dispersed environment there is water. The process of electrokinetic power mass transfer taking place here has its peculiarities, namely:

a) heteroporosity of the dispersed phase, that means inhomogenuity of capillary size depending on a wide scatter of particles size leading to overconsumption of power on the heating of a dispersed environment in large-sized cappillars;

b) complexity of an electrolyte composition of the dispersed environment. That means the availability of indifferent and nonindifferent electrolytes in solution leading, on the one hand, to the decrease of electrokinetic potential as a result of the increase of counter-ions concentration with the increasing solution of indifferent electrolytes. And on the other hand, it results in the ability of electrolyte ions to finish a lattice construction of the dispersed phase leading finally to electrokinetic potential fall;

c) difference of a hydrogen environmental index – pH on the neutral one could be greatly affected by the electrokinetic dispersed particle potential as "hydrogen and hydroxyl ions" have a high ability to be absorbed; the former – due to its short-range which allows one to come close to a hard phase surface; the latter– due to a large dipole moment;

d) dependence on the dispersed phase concentration – with diluting of the colloidal system, the electrokinetic potential should be increased as the thickness of a double electric layer is increased as a result of a counter-ion concentration decrease in the solution. Moreover, with diluting, the desorbtion of potential-determining ions from the dispersed phase surface could be observed and this must result in a decrease of electrokinetic potential. The phenomenon is typical of the electrophoresis in highly diluted sewage water;

e) dependence on the treatment temperature – with a temperature increase $\zeta$ – the potential should grow due to an intensity increase of counter-ion heat motion and a double electric layer thickness. However, simultaneously, the desorbtion of potential-determining ions could be increased, in this connection $\zeta$ - the potential is decreased;

f) instability of electrophysical and electrochemical properties of the dispersed phase which is inferred from a physical particle nature of the dispersed phase and a chemical activity of the dispersed environment.

## 3. Theory
Thus, the main peculiarity of the process of electrokinetic dispersed material treatment of mineral origin is a higher specific energy consumption in the process, a specific energy consumption dependence on the great number of noncontrollable and unmanageable factors due to the dispersed phase complexity and inhomogeneity. As such, several phenomena could occur within the material at once: electro-osmosis and electrophoresis, etc. Therefore, it is a challenging task to find a top system performance for generating electricity.

A real picture of electrokinetic phenomena should be described by equations for the response function not within the plane coordinates but within the quasispace (Fig.1), having no connections with real Euclidean space.

The necessity of solving the problem within the spatial coordinates corresponding to a real physical space emerges with disagreement of an external force action and capillary axis, as well as under harmonic external force action [1], which is more equivalent to reality.

The nomogram shows the electro-osmosis flat surface:

$$E - V_{av} \begin{cases} 1+3 \, \text{quadrants} - Electro-osmosis \\ 2+4 \, \text{quadrants} - osmo-emf \end{cases}$$

$$E - V_{f} \begin{cases} 5+7 \, quadrants - electrophoresis \\ 6+8 \, quadrants - phoro-emf \end{cases}$$

$V_{av} - V_f$ - power mass transfer caused by mechanical forces without a double electric layer.

In the light of the above described physical phenomenon the hypothesis for power generation with the no-machine method is very appealing. Therefore, starting with time of the stream function phenomenon discovery, there were attempts to be familiar with this direction. So, stream function measurements, electric resistance and ions absorption on rutile patterns in solutions depending on the composition and electrolyte concentration were conducted [2].

The value of $\zeta$-potential, surface conductivity $k_s$ and ions mobility were calculated during the experiment. High values of surface charge and $k_s$ compared with $SiO_2$ and noticeable values in the isoelectric point were found.
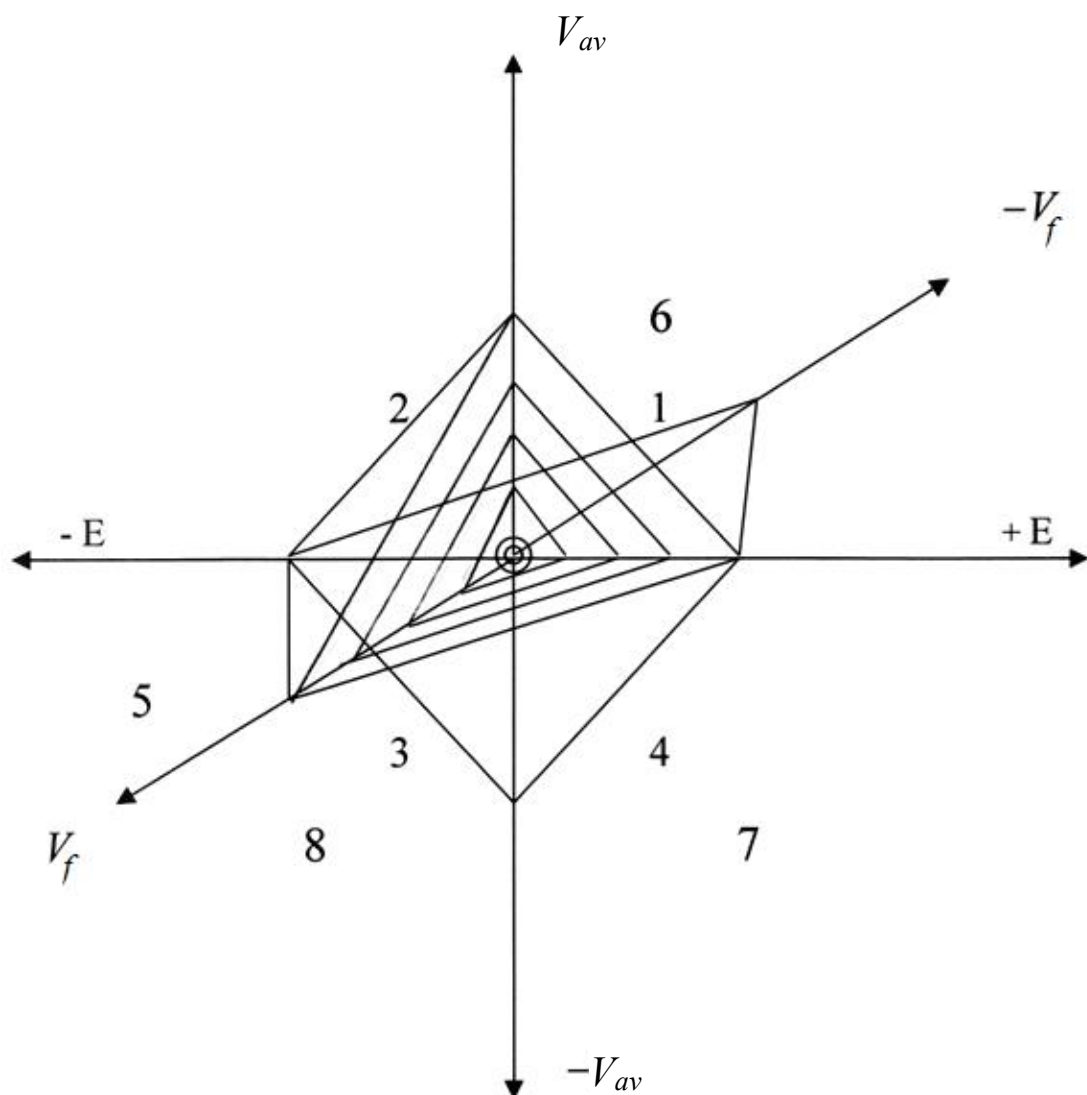


**Figure 1.** Phenomena space set of power mass transfer in dispersed materials: $E$ –electric field strength; $V_{av}$ –direction and motion speed of dispersed environment; $V_f$ – direction and motion speed of dispersed phase.

## 4. Process modeling
Theoretical studies of power conversion in electrokinetic processes involving multicomponent

mixtures were also carried out [3]. It is found that the flow of fluid through a porous body with charged surface could be used for converting mechanical power into electrical one.

Conversion efficiency or $\eta$ is calculated. Maximum value $\eta_m$ was calculated according to the theory of Morrison and Osterle. It is found that $\eta_m \approx 10^{-6}$ - it means that a greater part of input mechanical energy is dissipated converting into heat.

To define a real power conversion factor of pressure, fall on membrane, the experiments were carried out [4, 12-14]. Efficiency factor of conversion of pressure fall power into electrical is thought of as:

$$\eta = -\frac{i_d \cdot \varphi_d}{Q \cdot P} \quad ,$$

(1)

where $P$ – pressure fall between membrane surfaces;

$i_d \varphi_d$ - electric current and jump of potential in the measuring device;

$Q$ - extensive fluid speed in the membrane.

It is experimentally found that $\eta \approx 1...4\%$.

Obviously, such results give pause and rise to practicians that do not consider similar variant of self-contained supply. At the same time, practicians are not interested in total efficiency of the power conversion process but they have interest in integral characteristics of resulted power in output. On this assumption one could disregard power efficiency by formula (1) and shift to power generation using known dependencies.

Using the solution of the equation of Puasson-Bolzman [5] for small potentials, the dependence between medium extensive density of the charge in storage reservoirs $\rho_0$ and occurring potential difference between them $\Delta U$ could be obtained:

$$\Delta U = \frac{RT}{e^2 F^2 c} \cdot \rho_0,$$

(2)

where $e$ - charge of the main potential determining ion ;

$c$ - electrolyte solution concentration, mole/cm³;

$F$ - Faraday constant;

$R$ - gas constant;

It is proposed when discussing that in the system a constant pressure gradient $P = (p_1 - p_2)/l$ takes place, (water level difference between upper and lower pools) and the value $E = \Delta U$ has a constant steady-state value.

The equation for total electric current becomes:

$$I = \frac{1}{h}\int_0^h \rho v dy - \lambda(1+k)\Delta U \quad ,$$

(3)

where $\lambda$ – solution conductivity ;

$\rho(y)$ – extensive charge density in pores;

$k$ – factor including surface electric conductivity;

$\delta_s$ – surface charge density of the absorbed layer;

$u_s$ – ions mobility in the absorbed layer.

$$k = u_s \delta_s / h\lambda .$$

(4)

Taking into account the fact that the breakaway of a double electric layer is possible only by transferring of water from upper into lower pools, i.e. in volume $V$, with a speed of $v$ a membrane cross-section  from the equation could be considered:

$$\frac{Vl}{AS_m} \cdot \Delta U = I \,. \tag{5}$$

$$v = \frac{1}{\eta}\left\{\frac{P_y}{2}(y-2h) + \frac{\varepsilon\varphi_0}{4\pi}\left[\frac{ch\chi(h-y)}{ch\chi h} - 1\right]\Delta U\right\}, \tag{6}$$

where $y$ - coordinate, taking a reading of cell wall surface into depth of solution (sliding surface to be exact);

$\eta$ - fluid viscosity;

$\varepsilon$ - dielectric constant of fluid;

$\varphi_0$ -sliding surface potential;

$\chi$ - Debye constant;

$h$ - medium pore width.

Obviously, further calculation could be made in terms of mechanics of soil [6, 7], whence the equation follows provided by Darcy laminar filtering law:

$$V = k_f \frac{H}{L}, \tag{7}$$

where $L$ - filtration path length;

$k_f$ - filtration factor.

## 5. Conclusions
As research shows, to evaluate the performance potential of power generation from aquifers, it is necessary to define not only the colloidal properties of the membrane dispersed phase but also the filtration ground properties.

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