Electrohydroimpulse Equipment for Increase of the Output of Oil and Intake Wells

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Abstract – One of the problems arising at the operation of oil, input and water wells, is a falling of their output owing to the obstruction of punched holes and pore channels by mineral salts of various kinds and heavy components of oil. The Institute of Pulse Research and Engineering (IPRE) of the National Academy of Sciences of Ukraine offers a electric discharge method of the treatment of well bottom zones of oil and artesian wells by impulses of a high pressure and short duration, which allows to increase the output of wells and even to restore it up to the initial level. Developed and successfully used in practice of repair of the wells, the electric discharge devices "Skif", which are capable to function in the conditions of high hydrostatic pressures (up to 50 MPa) and ambient temperatures (up to 373 K) with a diameter of casing pipes of the wells over 130 mm, structurally consist of ground and submerged parts connected by a logging cable.

The operating feature of the device for treatment of water wells ("Skif-140") is a transmission of energy by a cable with direct current and charging of the storage element with AC of high frequency (20 kHz) that allows to provide high efficiency of the energy transmission and small size of charged block of the submerged part. The developed high-voltage pulse capacitors with paper-film insulation are reliable in work at ambient temperatures from 283 to 373 K.

Now the Institute develops a new generation of devices for processing oil well treatment, the feature of which is their opportunity to work at ambient temperatures up to 398 K with high efficiency owing to the change of the principle of the store charging, and also the application of capacitors with purely film insulation that will allow to reduce both cost of the equipment, and its running costs.

1. Introduction

One of the advanced lines of activity of the Institute of Pulse Research and Engineering (IPRE) of the National Academy of Science of Ukraine is a realization of the complex of research efforts on the use of electric discharge in liquid for the restoration of the output of oil and water wells [1]. This technology is used on the wells, deduced from operation for a time of repair. During the treatment the device moves in a well along its punched zone, generating electric discharges with intended frequency. At the same time the well cleanup takes place from detrimental wax, bituminous and heavy accumulations, and its porosity is restored in a zone of oil- and water-saturated beds. The appearance of one of such devices like "Skif" of the IPRE development is represented in Fig. 1.

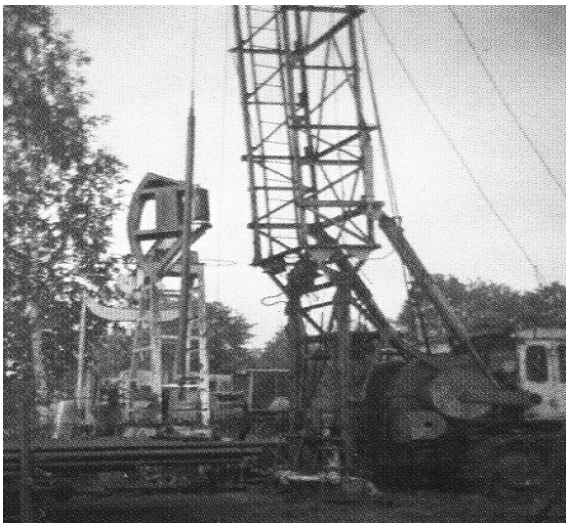

Fig. 1. Electric discharge device on the well

High qualifying standards to submerged discharge-impulse equipment are explained by specific conditions of its operation. It should be put to them a small size of diameter (130–200 mm) and possible axial curvature of well bore, and also high values of pressures and temperatures on the depths up to 5 km. To increase the efficiency of the given processing method, the experimental and theoretical investigations of electric discharge in liquid at different values of hydrostatic pressure (0.1–50 MPa) were undertaken. The measurements of discharge current and voltage in interelectrode space together with photorecording of the dynamics of plasma channel development were performed in works [2], [3]. The experimental results were compared with the results of computational modeling of submerged electric discharges [3], [4]. The mathematical model, represented in [4], includes equations of electric circuit, hydrodynamics, thermodynamics and wide-range equation of water state with pressure and temperature dependence of plasma conductivity. Such approach gives sufficiently detailed description of discharge characteristics and medium dynamics in the whole turn-down of change of its states from condensed to plasma one. The performance of these works

resulted in getting of specification of quantity of the electric discharge processes in conditions similar to the conditions of oil well treatment.

2. The Development of Equipment for Increase of the Output of Wells

The improvement of equipment characteristics laid in the development of subordinate characteristics of the constituent elements of equipment. For the improvement of characteristics of high-voltage capacitors, the electrophysical phenomena were investigated in a combined nonconductor of capacitor sections in powerful electrostatic fields. The influence of material properties of operating insulation, electrostatic field distribution in composite insulation and large-scale integration technology of capacitors on the storing energy density and lifetime were studied. The different structure of insulation, the distortion of electric field on the edges of capacitor sections, the discharge redistribution on the boundary surface of components of composite insulation, the presence of conductive and nonconducting switchings were taken into consideration. As a result of it, the permissible values of electric field voltage for different combinations of materials and thickness of film and paper-film composite insulation, the insulation insertion coefficient and film percentage in paper-film dielectric were determined [5]. High-voltage capacitors for submersible downhole devices, created in the IPRE, are notable for high strength of iron case. Their design allows to set off the effect of the temperature of ingrained liquid dielectric over the range from 233 to 373 K. The capacitors are reliable in work at the change of ambient temperature from 283 to 373 K and at the hydrostatic pressures up to 50 MPa. They can be easily combined with the help of threaded connection and high-voltage couplers into accumulating modules of necessary energy output. The characteristics of high-voltage pulse capacitors for submersible downhole devices are represented in the Table 1.

For decrease of dimension and mass of submerged part, the downhole device has the blocked structure and for charging of storage device, the transformation principle of the frequency of supply voltage is used. In this case two constructive types of charging units of capacitor storages can be used. From the point of view of lessening of energy loss and dimension of the device it is preferably to place the frequency converter directly in the submerged unit is carried out with direct current through the logging cable with minimum loss and, therefore, the installed capacity of electrical equipment is minimal in that case. Such conceptual design is used today in the device “Skif-140”, that is being developed for water well treatment. Its construction includes a single-phase half-bridge resonance transistor chopper, assembled from transistors of IGBT class of IRG4PG50U model.

For decrease of overheating of semiconductor elements of the device, that is possible on large depths of treatment, which are typical for oil wells, the frequency converter can be situated surface marking near the well. In that case the charging unit lives on high-frequency alternating current through the load cable. Usually the length of the cable varies within the limits from 1.5 to 7 km and depends on the depth of electric discharge treatment of the oil-bearing bed. The devices for oil well treatment, like “Skif”, include both ground and submersible equipment. The electric circuit of charging unit of the device, represented in Fig. 3, includes a rectifier bridge and a bridge inverter (1000 Hz, 200-900 V), constructed on the base of TB class thyristors. High-voltage transformer and high-voltage rectifier, that was assembled according to the voltage-doubling circuit, form the submersible device. The appearance of the frequency converter of the device “Skif-100” for the oil well treatment is represented in Fig. 4.

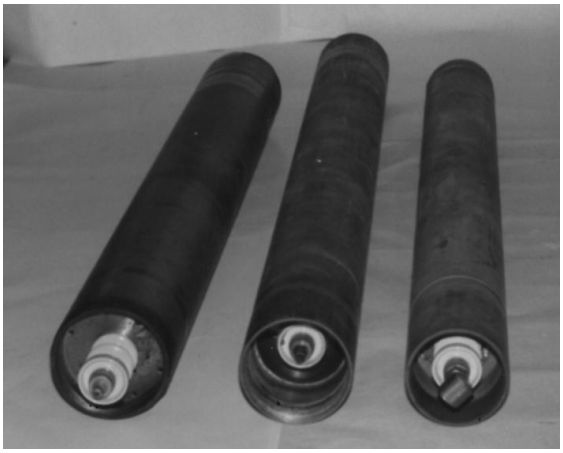

Fig. 2. High-voltage pulse capacitors for downhole devices

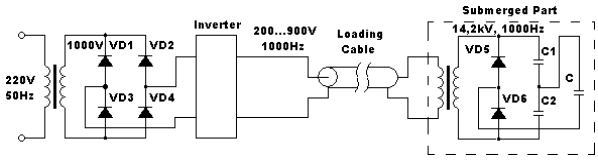

Fig. 3. Electric circuit of charging unit of the device for oil well treatment

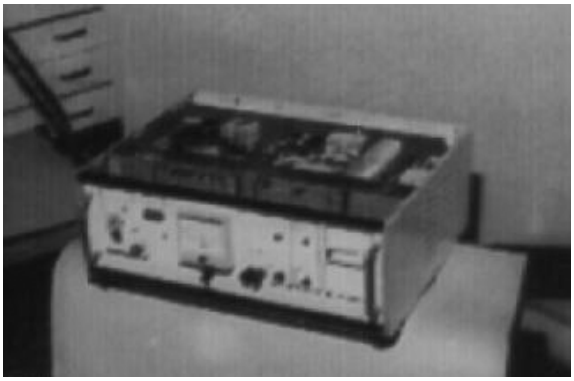

Fig. 4. Frequency converter of the downhole device “Skif-100”

The technical characteristics of a number of models of the devices like “Skif” are represented in the Table 2.

Table 1. High-voltage pulse capacitors for submersible downhole devices

Capacitor type	U, kV	C, μF	W, J	L, μH	w_v, J/dm^3	Lifetime, charge-discharge cycles	Mass, kg	Maximum ambient temperature, K	Case dimensions, mm
CF 4M.05.000	30	0.8	360	1.25	31.2	$7.2 \cdot 10^5$	35	353	∅114, H_c = 1132
CF 100.05.000	30	0.8	360	1.25	39.1	$8.5 \cdot 10^5$	28	373	∅102, H_c = 1128
CF 140.05.000	30	3.3	1485	0.6	94.6	$5.2 \cdot 10^5$	31	313	∅140, H_c = 1020

Table 2. Electrohydroimpulse devices for oil- and water-well treatment

Characteristics	Type of the device		
	"Skif-4"	"Skif-100"	"Skif-140"
Power consumption, kW	2	2	1
Case diameter, mm	114	102	140
Length, m	5.5	5.7	2.0
Storage voltage, kV	30	30	30
Storage capacitance, μF	2.4	2.4	3.3
Working temperature, K	≤ 353	≤ 373	≤ 300
External pressure, MPa	≤ 35	≤ 50	≤ 0.2

3. The Prospect of the Development of Electric Discharge Equipment for Oil Well Treatment

Today in the IPRE of the National Academy of Sciences of Ukraine are carried out the investigations on the increase of the efficiency of workable equipment for the enlargement of the oil inflow into the wells. Thus, one of the tasks is to create an electric discharge device, functioning stable and efficiently at ambient temperatures up to 398 K. The capacitors with a purely film dielectric are being developed now, that will allow to shorten the time of their production cycle, to reduce power inputs, and consequently, the cost of capacitors under simultaneous increase of specific storing energy. The updating of the process of power transmission from the ground transmitter to the storage element is being realized in two directions. First, the charging circuit is being worked out, which is similar to the used one in the device for water well treatment "Skif-140", and it will allow to increase considerably the degree of efficiency owing to the power transmission by a connecting cable with direct current. At considerable ambient temperatures the given circuit can be applied only with the use of additional cooling elements of the transistor chopper of devices, therefore the second way of the development is the usage of power transmission by a cable with alternating current. However, unlike the existing works nowadays, in the capacity of current-limiting element of charging circuit the inductor is used, which is located on the ground surface in the frequency converter and enables to compensate partly the reactive energy, used by distributed capacitance of the cable.

Also the investigations are carried out, which are directed to the increase of the energy liberation efficiency in the interelectrode distance owing to the use of discharge in workspace capacity, both as aqueous electrolyte with optimal specific conductance, isolated from external environment by a resilient casing, and as water-oil emulsion being the natural liquid that fills the wells.

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