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Research on power supply technology for improving recovery rate of low permeability reservoir

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Abstract: **This paper set up the model with the action of external electric field of the permeation and streaming law of two- phase in different structures. Based on electron-osmosis theory, receive the limited-element equations of two-phase flow. And then obtain exact solution of the problem by using analytic method of COMSOL Multi-physics. With water saturation change research gap structure under applied electric field circumstance in the influence of two phase flow, to reveal the direct current field to influence of oil-water two phase flow of gap medium provides a certain theoretical basis. For the convenience of field test, this paper use of Buck circuit, the soft switch technology and double closed loop control circuit for the design of dc field, such as in the MATLAB simulation and verification, to get stable output of dc field.**

Keywords: Direct Current (DC) electric field; Crevice medium; Recovery ratio; Water saturation

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1. Introduction

The shortage of oil and gas has always been a big problem for all countries in the world. Most of the oil fields in China have entered the high or ultra-high water cut period one after another; the newly added reserves are mainly thin oil layers with low permeability and poor physical property and the conventional oil extraction technology is not suitable for most of them. To find a reasonable method to solve the problems encountered in the production of oil and gas has become an urgent problem to be solved in the oilfield development. It is a new technology in the field of oil production to improve the recovery rate of crude oil by improving the electric conductivity, electrochemistry, electro-osmosis and electric heating effect of electric field. Its advantages lie in no pollution, Simple process and low cost. Moreover, electrical energy, as a secondary energy source, is easy to get, and the way to get it is environmentally friendly and pollution-free. The utilization of secondary energy sources to improve the recovery of non-renewable primary energy is also the advantage of the DC electric field. Therefore, it has a great potential to use the external electric field to improve the recovery rate.

In this paper, two-dimension gap model is selected as the calculation model. Based on the study of single medium percolation by electro-osmotic theory, a mathematical model of oil and water two-phase flow in low permeability gap medium is proposed and established. Numerical simulation using the limited-element theory is carried out in the computer software.

2. Derivation of limited-element equation of two-phase flow under the applied electric field

The Limited-element module of the pressure

According to the Darcy equation:

$$\frac{d}{dx}\left(\frac{kk_{rw}}{\mu_w}\frac{dp_w}{dx}\right)-\frac{d}{dx}\left(\frac{\varepsilon\xi_{sw}\phi k_{rw}}{\tau'\mu w}\frac{d\Phi}{dx}\right)=-\phi\frac{\partial S_w}{\partial t} \quad (1)$$

$$\frac{d}{dx}\left(\frac{kk_{ro}}{\mu_o}\frac{dp_o}{dx}\right)-\frac{d}{dx}\left(\frac{\varepsilon\xi_{wo}\phi k_{rw}}{\tau'\mu w}\frac{d\Phi}{dx}\right)=-\phi\frac{\partial S_o}{\partial t} \quad (2)$$

Adding both sides of the (1) and (2), resulting in:

$$\frac{d}{dx}\left(\frac{kk_{ro}}{\mu_o}\frac{dp_o}{dx}+\frac{kk_{rw}}{\mu_w}\frac{dp_w}{dx}\right)+\frac{d}{dx}\left(\frac{\varepsilon\xi_{so}\phi k_{ro}}{\tau'\mu_o}\frac{d\Phi}{dx}-\varepsilon\xi sw\phi krwt'\mu wd\Phi dx=-\phi\partial(Sw+So)\partial t\right) \quad (3)$$

Combined with saturation equation and capillary force equation, we can get:

$$\frac{d}{dx}\left(\left(\frac{kk_{ro}}{\mu_o}+\frac{kk_{rw}}{\mu_w}\right)\frac{dp_w}{dx}\right)+\frac{d}{dx}\left(\left(\frac{\varepsilon\xi_{so}\phi k_{ro}}{\tau'\mu_o}-\varepsilon\xi sw\phi krwt'\mu wd\Phi dx=0\right)\right) \quad (4)$$

Both sides of the equation are multiplied by the δp, then using integration by parts in all areas, yielding:

$$\left[\left(\frac{\varepsilon\xi_{so}\phi k_{ro}}{\tau'\mu_o}-\frac{\varepsilon\xi_{sw}\phi k_{rw}}{\tau'\mu_w}\right)\frac{d\Phi}{dx},\frac{d\delta p}{dx}\right]_\Omega+\left[\left(\frac{kk_{ro}}{\mu_o}+kkrw\mu wdpdx,d\delta pdx\right)\right]_\Gamma=kkro\mu o+kkrw\mu wdpdx,d\delta pdx\Omega \quad (5)$$

Where the δp isvariational part of pressure.

Considering the boundary condition equation, we can get:

$$\left[\left(\frac{\varepsilon\xi_{so}\phi k_{ro}}{\tau'\mu_o}-\frac{\varepsilon\xi_{sw}\phi k_{rw}}{\tau'\mu_w}\right)\frac{d\Phi}{dx},\frac{d\delta p}{dx}\right]_\Omega=\left[\left(\frac{kk_{ro}}{\mu_o}+kkrw\mu wdpdx,d\delta pdx\Omega\right)\right] \quad (6)$$

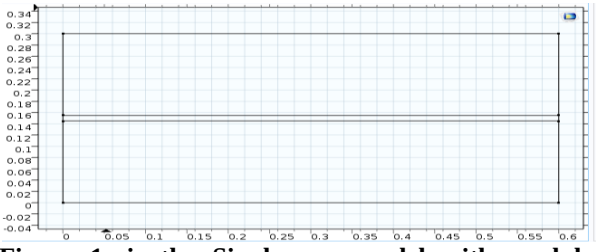

Figure 1. is the Single gap model with module length 0.6m, module width 0.3m, module height 0.3m, the number of gap is 1.

3. Simulation of different gap quantity model under external electric field

In order to study the effect of the external electric

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field on the water saturation in the gap medium module, we analysed the result of the electric field on the two phase flow of multi gap which are obtained by simulation. Three model structures with different gap numbers as follows:

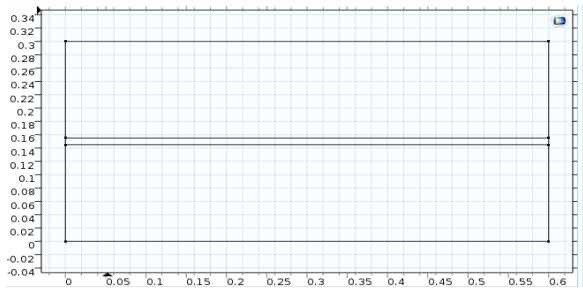

Figure 2. is the Multi gap model with module length 0.6m, module width 0.3m, module height 0.3m, the number of gap is 3.

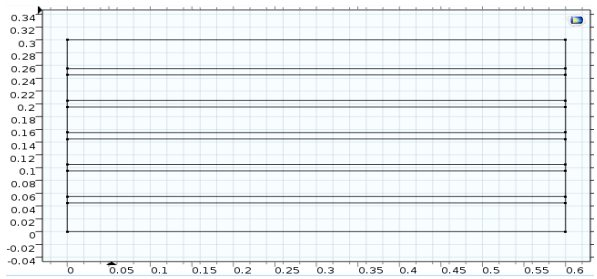

Figure 3. The Multi gap model with module length 0.6m, module width 0.3m, module height 0.3m, the number of gap is 5.

4. Design of DC regulated power supply for 160V applied electric field

4.1. Simulation of DC regulated power supply

Figure 4 is the simulation model of the whole circuit of 160V DC regulated power supply. Each element in the model is given by design. After a certain period of work, the circuit reaches stability. The uncontrolled rectifier, PWM control signal and the output voltage of the whole circuit are displayed in the oscilloscope. The input and output diagrams of the whole circuit are also displayed in the oscilloscope. For the convenience of observation, the input voltage U_i, the PWM control signal and the output voltage-current waveform of the whole circuit are given. Which are showed in Figure 5-8.

4.2. Stability test of the regulated DC power supply

For the underground complex and load change with depth problems, we test the stability of the designed regulated DC power supply by using Matlab/Simulink toolbox in this section. Adding load disturbance to the original model at the time t=0.3s. The output waveform of regulated DC power supply is showed in Figure 9

As shown in Figure 9, although temporarily low, the output voltage can still be stabilized at 160V after a short time double closed loop regulation, which proved that the designed regulated DC power supply is stable.

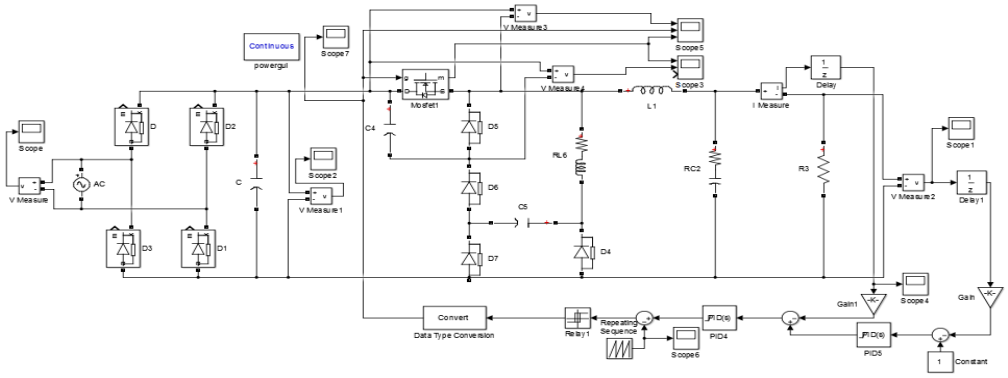

Figure 4. Whole simulation diagram of DC regulated power supply.

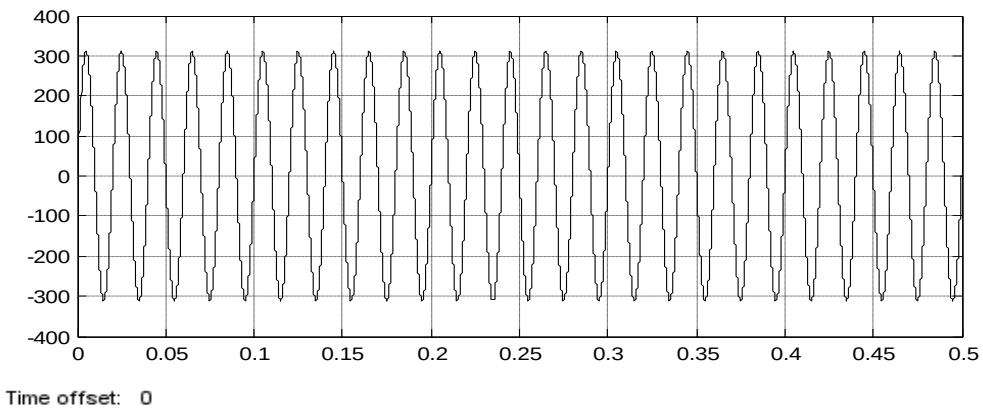

Figure 5. Input voltage.

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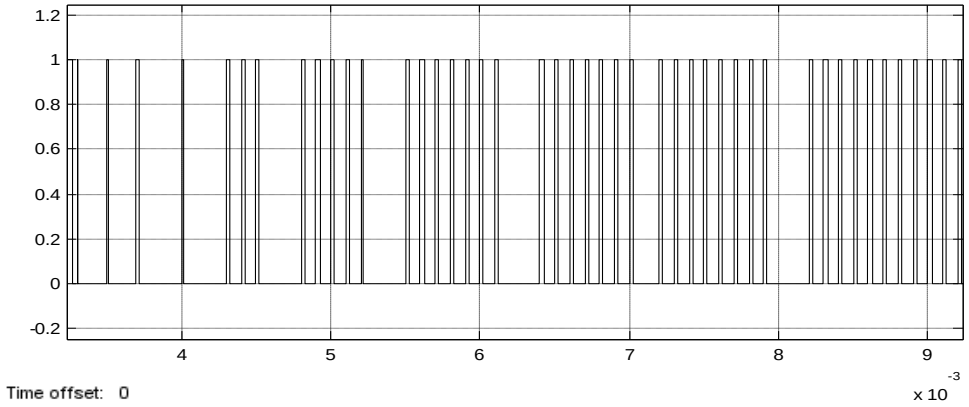

Figure 6. PWM control signal waveform.

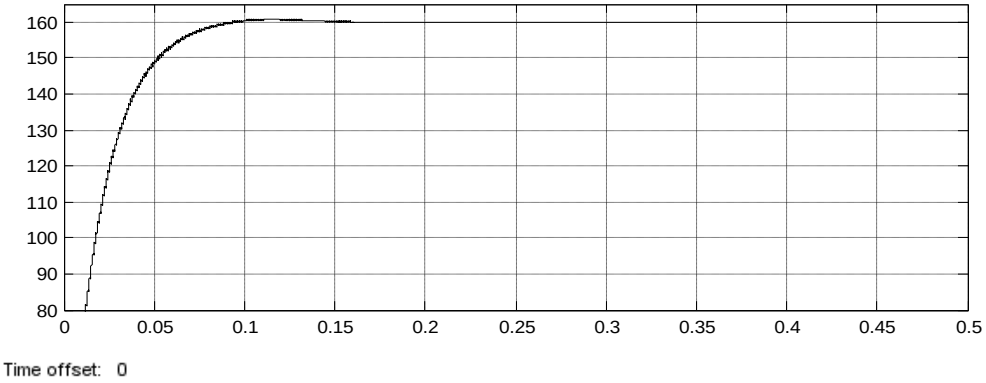

Figure 7. The output voltage waveform of the whole circuit.

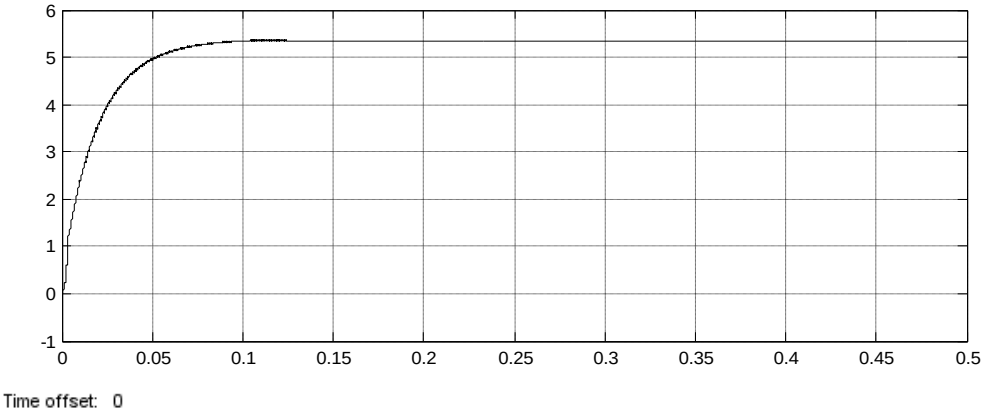

Figure 8. The output current waveform of the whole circuit.

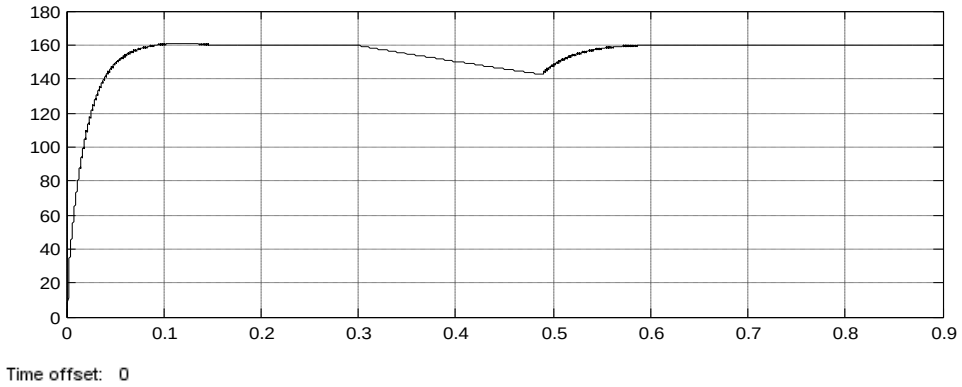

Figure 9. The output current waveform of the whole circuit.

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5. Conclusion

A mathematical model of oil and water two-phase flow in low permeability gap medium is proposed and established which breaks throughthe limitation of research ononly single medium.

By using COMSOL computer software, numerical simulation is carried out by limited-element method and the optimal potential value is determined.

The regulated DC power supply is designed in Matlab to ensure the stable output of theapplied electric field and its stability is verified in order to further experiments.

Acknowlegment

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References

[1] J.J. Xu, Y.C. Xu, L.M. Yan. International Journal of Online Engineering, 9 (2013) 24-29.
[2] J.J. Xu, Y.Y. Zi. International Journal of Applied Mathematics and Statistics, 43 (2013) 318-326.
[3] L.C. Zhu, J.J. Xu; L.M. Yan. Multimedia Tools and Applications, 27 (2016) 1-20.
[4] L.M. Yan, Y.S. Zhu. Transactions of China Electrotechnical Society, 29 (2014) 260-268.
[5] L.M. Yan, J. Cui. Electric Machines and Control, 18 (2014) 78-84.
[6] L.M. Yan, Y.B. Xie, J.J. Xu. Journal of XI'ANJiaotong University,47 (2013) 117-123.
[7] J.J. Xu, D. Gai, L.M. Yan. Basic & Clinical Pharmacology & Toxicology, 118 (2016) 38-38.
[8] J.J. Xu, B.E. Wang, L.M. Yan, Z.P. Li. Transactions of China Electrotechnical Society, 3 2(2017) 214-223.

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