Automatic Vertical Drilling System

Science & Technology Management Department

2013

CHINA NATIONAL PETROLEUM CORPORATION

CNPC AVDS Technology — Impartial
Pinpiont on Target!

Contents

China National Petroleum Corporation (CNPC) is a state-authorized investment agency and a state holding company. On July 1998, with the implementation of the Institutional reform of the State Council, CNPC was reorgnized to become an integrated oil company of cross-regions, cross-industries and cross-countries, it adopts modern enterprise system to realize the integrations of upstream and downstream operations, internal and external trade, production and marketing. CNPC's business covers six main sectors: oil and gas operations, petroleum engineering service, petroleum engineering construction, petroleum equipment manufacturing, financial services and new energy development. In 2012 CNPC produced 110 million tons of crude oil and 79.82 billion cubic meters of natural gas, while crude processing volume reached 191 million tons. The total revenue of RMB 2,690 billion with a profit of RMB139.1 billion had been achieved the same year.

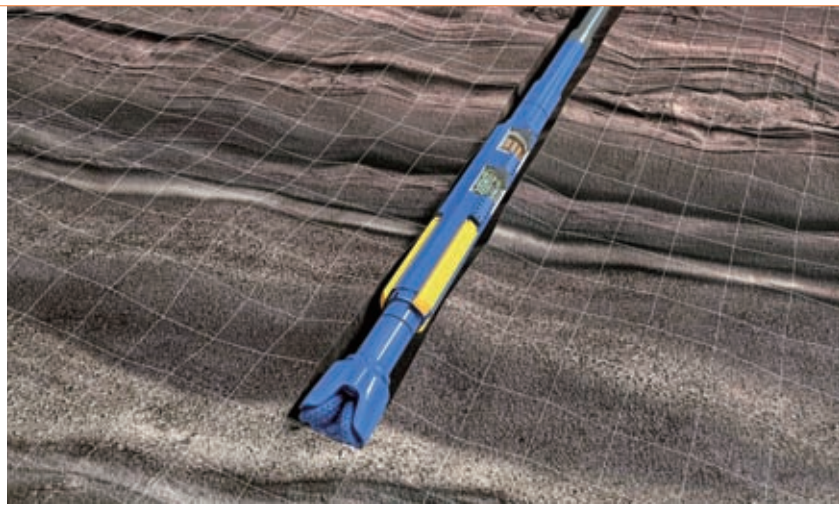
CNPC was ranked 4th among the world's largest 50 oil companies and 6th in Fortune Global 500 in 2012.

CNPC strictly follows by the combined strategies of increasing resource capacity, expanding market shares and consolidating the international role, and persists in regarding technical innovation as a key framework to advance technological progress. To develop its core businesses, focuses will be placed on the solutions of key bottleneck technologies and key proprietary technologies. Thanks to continuously improving of the technical innovation system, optimizing the configuration of technological resources and strengthening the construction of strong talent teams, CNPC's technological creativity has been considerably upgraded. Consequently, a large number of technologies have been developed independently, with its own intellectual property.

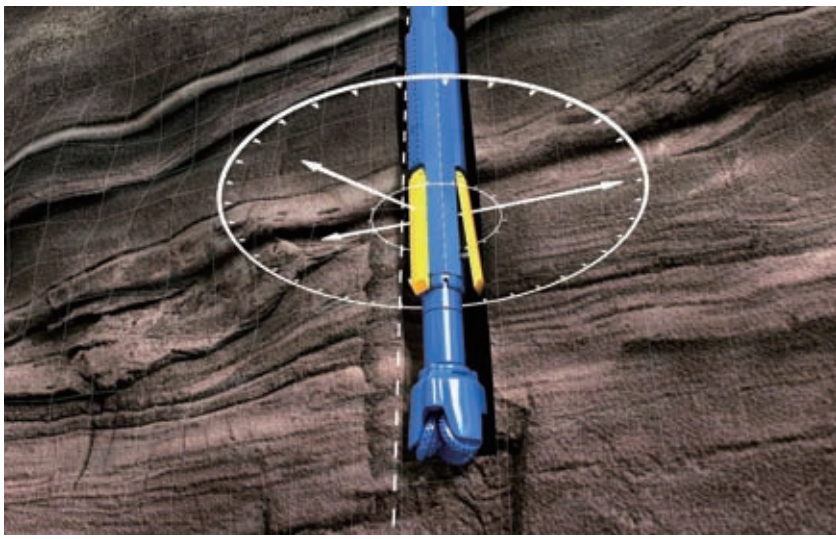
Automatic Vertical Drilling System is one of representatives for major innovations of CNPC.

CLEAN ENERGY SUPPLY FOR BETTER ENVIRONMENT

1 INTRODUCTION



Automatic vertical drilling system



The principle of automatic vertical drilling system

Keeping a close eye on the technological problems of the world petroleum drilling engineering, CNPC took 7 years to successfully develop the Automatic Vertical Drilling system with fully independent intellectual property rights and has created a new-generation high-end drilling equipment.

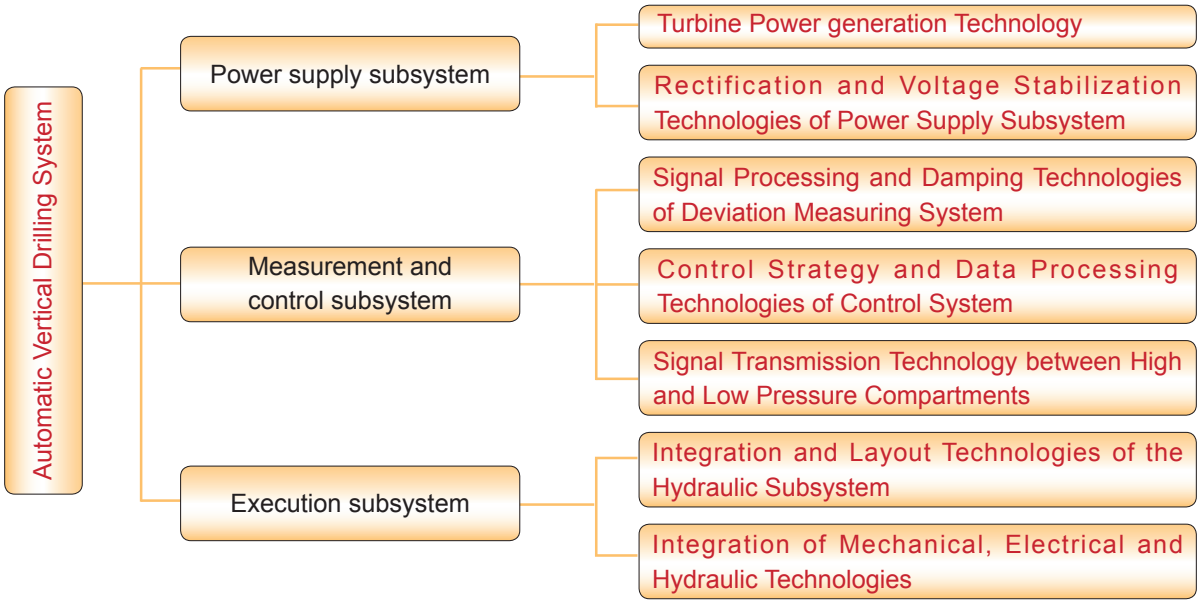
The system consists of three parts, i.e., power supply subsystem, measurement and control subsystem and hydraulic execution subsystem. It adopts modular design due to which it has stable and reliable performance and simple and convenient operation and maintenance. It features automatic downhole closed-loop control, vector control straightening force, mud turbine power generating and contactless power transmission, etc.

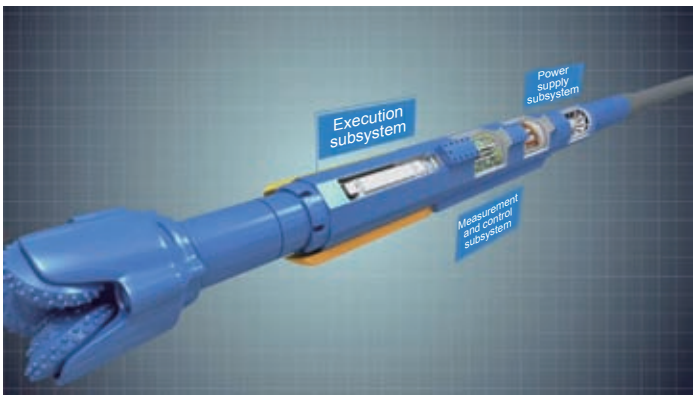
The successful R&D of the automatic vertical drilling system provides economical and efficient technological means to solve technological drilling problems in easily inclined intervals such as piedmont high and steep structure, stratum with big dip and thrust nappe stratum, and it can effectively free WOB and increase drilling speed.

When the automatic vertical drilling system is utilized in practical drilling process, its turbine generator can supply power to the measurement and control subsystem via contactless rotary voltage transformation system. If wellbore is deflected, the downhole measurement and control subsystem will judge and analyze first and then give an order to the execution system to make corresponding plunger guide block to extend along the direction of high side of the well under the effect of driven pump, and so under the effect of reverse direction force of sidewall, bit will have horizontal straightening force to make the tool to drill along the direction of inflection and then the wellbore will come back to the vertical trajectory. When the wellbore is back to vertical trajectory, the downhole measurement and control subsystem will give an order again to the execution system after judgment and analysis, and then driven pump stops working and bit will drill vertically with no straightening force. The automatic downhole closed-loop control will not only increase the control accuracy of wellbore trajectory, but also save the

time for adjusting drilling tool, by which the purpose to control deviation and increase drilling speed is achieved.

The automatic vertical drilling system can develop downhole closed-loop drilling with an integration of mechanical system, electrical system and hydraulic system, and its technological framework can be divided into three subsystems as follows: power supply subsystem, measurement and control subsystem, and execution subsystem.



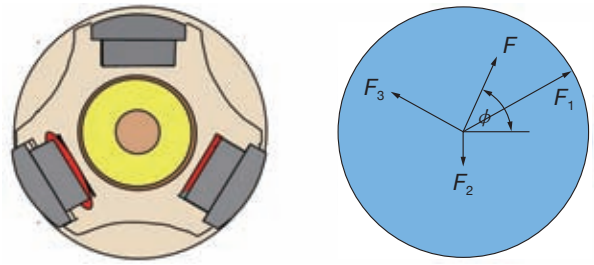


3 Subsystems of vertical drilling system

2 UNIQUE TECHNOLOGIES

2.1 Technical Features and Advantages

(1) Integration of mechanical, electrical and hydraulic technologies;
(2) Continuous measurement of deviation from vertical direction;
(3) Independent power generation by turbine;
(4) Automatic guide control of downhole closed-loop;
(5) Monitoring and measuring deviation along drilling.



Schematic diagram of plunger stress of the vertical drilling system

2.2 Scope of Application

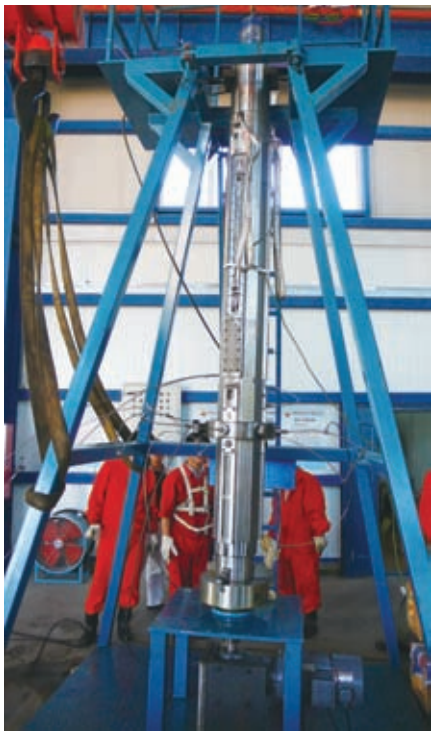
The automatic vertical drilling system is mainly applied to prevent and straighten deviation of high and steep stratum, stratum with big dip, and thrust nappe stratum, and it can greatly free WOB, increase drilling speed and save drilling cost.

ϕ311mm(12¼in) / ϕ333mm(13⅛in) Automatic Vertical Drilling System

Technical indexes			
Hole size	ϕ311mm/ ϕ333mm	Lateral force	17.6-20.1kN
Tool OD	ϕ308mm/ ϕ330mm	Maximum tensile strength	2100kN
Tool ID	ϕ72mm	Maximum torsional strength	41000N·m
Tool length	5m	Hole deviation control range	<1°
Maximum working OD	ϕ335mm/ ϕ357mm	Hole deviation control accuracy	0.1°
Maximum operating temperature	125℃	Maximum working pressure	105MPa
Maximum rate of over-all angle	2°/30m	Longitudinal vibration requirement	<20g
Drilling fluid displacement required	40-70L/s	Transverse vibration requirement	<5g

ϕ406mm(16in) / ϕ445mm(17½in) Automatic Vertical Drilling System

Technical indexes			
Hole size	ϕ406mm/ ϕ444mm	Lateral force	19-20.1kN
Tool OD	ϕ404mm/ ϕ442mm	Maximum tensile strength	4000kN
Tool ID	ϕ75mm	Maximum torsional strength	63000N·m
Tool length	5m	Hole deviation control range	<1°
Maximum working OD	ϕ438mm/ ϕ476mm	Hole deviation control accuracy	0.1°
Maximum operating temperature	125℃	Maximum working pressure	105MPa
Maximum rate of over-all angle	2°/30m	Longitudinal vibration requirement	<20g
Drilling fluid displacement required	40-70L/s	Transverse vibration requirement	<5g



Lab test

2.3 Power Supply Subsystem

The power supply subsystem is composed of mud turbine generator, ballast inversion sub and rotary non-contact power transmission system. The power energy generated by mud driven generator will be rectified and wave-filtered via drill pump, and then transferred to other parts of the automatic vertical drilling system through non-contact rotary power transmission system. It can provide continuous and stable power supply to support the whole system.

2.4 Measurement and Control Subsystem

The measurement and control subsystem is located on the upper end of guide sleeve, and it mainly consists of deviation angle measurement sensor and control circuit that includes digital circuit and analog circuit, and control signal and driving signal. The circuit can be mainly divided into drive circuit, thrust measurement circuit and human-machine interface circuit. As the nerve center of the automatic vertical drilling system, the measurement and control subsystem can give orders to the execution system.

When the drilling system is working, the deviation angle measurement sensor will monitor the changes of deviation angle all the time and transfer the results to the control circuit which will determine whether the angle is out of limits. If out of limits, the control circuit will calculate high side direction; thrust and driving power according to the deviation angle received and then give order to the execution system.

Piedmont

2.5 Execution Subsystem

As the terminal of the automatic vertical drilling system, the execution subsystem is placed on the bottom of guide sleeve. In case of deviation, it will timely respond to the order from the measurement and control subsystem to extend the guide block at high side of wellbore to sidewall, and so horizontal straightening force will be generated near bit. When there is no deviation, it will promptly respond to the order given by the measurement and control subsystem to make guide block to stop working and to have straightening force disappeared. The execution subsystem adopts modular design that integrates mechanical system with electrical system and hydraulic system, and it is mainly consists of 3 DC generators and corresponding oil pump, hydraulic system, plunger guide block and guard plate.

Drilling site

3 TYPICAL CASES

The automatic vertical drilling system has been applied to the on-site tests and applications of 6 wells in Xinjiang oilfields with accumulated footage 3489.14m, pure drilling time 122.519h, average mechanical drilling speed increased by 2 to 3 times and deviation controlled within 0.5°. It realizes continuous control of deviation in drilling, and its adaptability, stability and deviation control accuracy have reached international advanced level.

(1)In May 2012, ϕ444.5mm automatic vertical drilling system was put into on-site test in the second spudding interval of HUK22 well, Hutubi gas storage project.

BHA:

ϕ444.5mm PDC bit+ϕ445mm vertical drilling tool+ϕ228.6mm short drill collar+ϕ228.6mm nonmagnetic short drill collar+ϕ444mm stabilizer+ϕ228.6mm drill collar×6 pieces+ϕ203.2mm drill collar×7 pieces+ϕ203.2mm bumper jar while drilling+ϕ203.2mm drill collar×2 pieces+ϕ139.7mm drill pipe.

The automatic vertical drilling system was run at the well interval of 1106~1910m with footage 804m, pure drilling time 60.52h and all deviations controlled within 0.5°.Drilling parameters used: WOB: 80~120kN, rotary speed: 90r/min, displacement: 60L/s, density: 1.25~1.30g/cm^3, pump pressure: 15~18MPa, torque: 10~20kN·m, viscosity: 45~55s.

The average mechanical drilling speed reaches 13.28m/h, and the WOB applied by the same type of

Onsite application of the automatic vertical drilling system

PDC bit in the same interval of adjacent well is generally 60kN, compared to which the average mechanical drilling speed is increased by over 1 time. The test result indicates that the system structure is of reasonable design and can realize continuous control of deviation in drilling, and its adaptability, stability and deviation control accuracy have reached international advanced level.

(2)In January 2013, ϕ311mm vertical drilling system was put into on-site test in Ya K1-7 well, Yumen oilfield.

BHA:

ϕ311mm bit+ϕ311mm vertical drilling tool+ϕ203mm deviation monitoring system+ϕ311mm stabilizer+ϕ229mm dill collar (3 pieces)+ϕ203mm dill collar (8 pieces)+ϕ177.8mm dill collar (3 pieces)+ϕ127mm drill pipe.

The vertical drilling tool was run at the well interval of 630~701m with total footage 71m, WOB 80~160kN, average mechanical drilling speed 7.04m/h, and the highest mechanical drilling speed 9.66m/h. Compared to the regular BHA of drill crew, the average drilling speed is increased by 2.34 times and deviation is decreased from 2.1° to 0.2°, which indicates that its application effect is significant.

On-site test of the vertical drilling system

Test of the vertical drilling system on Huobei well 2

4 R&D EQUIPMENT

CNPC has over 160 sets of drilling R&D and test instruments and equipments including multi-functional testing machine, 3-axle nonmagnetic revolving table, combined vertical drilling test system, drill fluid analysis and testing instrument, makeup and breakout machine and drawing machine, etc. with newness factor up to 0.8.

Functional wellhead testing machine

Lab test of the vertical drilling system

Makeup and breakout machine and drawing machine

5 QUALIFICATIONS AND STANDARDS

CNPC passed the ISO9001 system certification in 1999, HSE/OSH system certification in 2002, and API Q1 management system certification in November 2011.

HSE System Certification

HSE System Certification

OHS

OHS

QMS

QMS

API Certification

ISO 90012008 Certification

ISO–TS29001 Certification

6 EXPERT TEAM

Xu Shuqian Senior expert in drilling technology. He is engaged in the research and application of oil well cement and supporting additives, cementing and completion process technologies, directional well and horizontal well drilling process technologies, and underbalanced drilling process technologies. He has led and completed several drilling engineering programs of 1 megaton level new oilfields. He has won 18 over-provincial/ministerial scientific research achievement prizes.

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Chen Ruoming Senior expert in drilling technologies. He has undertaken many national and corporation projects and has long been directing technological innovation and new technology promotion and other works. He is engaged in complicated deep well completion process, directional well and horizontal well, branch well and underbalanced well drilling and related aspects. He has won 10 provincial/ministerial scientific research achievement prizes.

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Ai Caiyun Senior expert in drilling technology. He is engaged in R&D of drilling tool, drilling equipment and underbalanced drilling process. He has directed introduction of air drilling equipment for several times and was responsible to organize site construction of dozens of underbalanced wells and has led R&D of automatic vertical drilling tools. He has won 2 provincial/ministerial scientific research achievement prizes.
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Wang Xin Senior expert in drilling technology. He is engaged in the process technologies of directional well and horizontal well. He has organized and undertaken the design works of many deep wells, complicated wells and special wells. He has won 2 provincial/ministerial scientific research achievement prizes.
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