AC and DC Drives for Oil Drilling
AC and DC Drives for Oil Drilling

SIMOVERT Masterdrives
SIMOREG DC Master

1. Application Background 5
2. Description of Machine 6
3. Special Requirements of Drilling Machine and its Solution 9
4. System Configuration 10
5. The Special Features of our Solution 15
6. Our Competitive Edge 18
7. Several extra Topics for Discussion 18
8. Customer Benefits and Advice for Calculation 20
9. Successful Projects 21
10. References 23
11. Relevant Documents 23
12. Contacts 23
1. Application Background
   - Overview of Oil Industry ................................................................. 5
   - History of Drilling Machine in China ............................................... 5
   - Drilling Procedure ............................................................................ 5
   - Classification of Drill Machine ......................................................... 6
   - Drilling Machine Trends ................................................................... 6

2. Description of Machine
   - Power Supply .................................................................................. 6
   - Rolling System .................................................................................. 6
   - Rotating System ................................................................................ 7
   - Circulation System ............................................................................ 7
   - Two Types of Drive for Drill ............................................................. 8
   - Typical Load Analysis ....................................................................... 8

3. Special Requirements of Drilling Machine and its Solution
   - Specific Standards ............................................................................. 9
   - Small Power Supply ......................................................................... 9
   - Size Limitation .................................................................................. 9
   - Reliability .......................................................................................... 9
   - Special Motor .................................................................................... 10

4. System Configuration
   - Typical Arrangement of electrical Parts ......................................... 10
   - System Configuration 1 (DC) ............................................................. 10
   - System Configuration 2 (DC) ............................................................. 11
   - System Configuration 3 (AC) ............................................................. 12
   - System Configuration 4 (AC) ............................................................. 13
   - Recommended Communication Configuration 1 (PROFIBUS) ........... 13
   - Recommended Communication Configuration 2 (Remote I/O) ........... 14

5. The Special Features of our Solution
   - Pedal Switch .................................................................................... 15
   - Rotating Tray Inhibition ................................................................. 15
   - Zero Point Protection for Winch ....................................................... 15
   - Current Limitation ............................................................................ 16
   - Load Distribution ............................................................................... 16
   - Power Limitation ............................................................................... 17

6. Our Competitive Edge ....................................................................... 18

7. Several extra Topics for Discussion
   - DC Drives v.s. AC Drives ................................................................ 18
   - Single Motor or Double Motors ....................................................... 18
   - System Redundancy .......................................................................... 19
   - Influence of the Energy stored in the DC Link Capacitor ............... 19

8. Customer Benefits and Advice for Calculation
   - Customer Benefits ........................................................................... 20
   - Advice for Comparison Calculation ............................................... 20

9. Successful Projects
   - Application 1 (DC) ......................................................................... 21
   - Application 2 (AC) ......................................................................... 22

10. References ......................................................................................... 23

11. Relevant Document ........................................................................... 23

12. Contacts ............................................................................................ 23
1. Application Background

Overview of Oil Industry

In the past century, as the most important resource, oil greatly influenced the development of human society. In addition, with the development of oil chemistry, oil is closely connected with almost every part of our everyday lives, like food, cloth, and housing. Figure 1 shows the profile of oil industry:

![Profile of Oil Industry](image)

**Figure 1:** Profile of Oil Industry

History of Drilling Machine in China

At the beginning of 1980s, the electrical drill started to enter the Chinese market. All of these were direct imports. In 1997 Siemens Electrical Drives Ltd. and local mechanical supplier manufactured the first totally digital-controlled frequency converter-fed drilling machine in China. In 1998, XPEIC and ROSS HILL signed a contract to develop SCR drill market. After that point, the electric drill market developed into a booming market. However, this development brought more fierce competition.

**Drilling Procedure**

As shown in Figure 1, the drill is the first node of the oil industry chain. But exploring an oil well is by no means an easy job. Figure 2 shows the general process of drilling an oil well.

![Drilling Procedure](image)

**Figure 2:** Drilling procedure
Classification of Drill Machine

**Type of drive:**
- Mechanical drive
- Electrical drive
- Hydraulic drive

**Size according to depth:**
- Small oil drill < 2000 m
- Medium oil drill 2000 – 4500 m
- Deep oil drill 4500 – 6000 m
- Deeper oil drill 6000 – 9000 m
- Deepest oil drill 9000 – 15000 m

**Environmental conditions:**
- Ordinary land oil drill
- Desert oil drill
- Polar area oil drill
- Sea (includes offshore) oil drill

Drilling Machine Trends

- Top derrick drive system
- Super deep drill
- AC drive
- Close loop drill and remote control
- Auto drill

2. Description of Machine

**Figure 3: Profile of Derrick**

**Figure 4: Diesel Generator and Control House**

**Power Supply**

The power ranges from 800 kW to 4000 kW, which is normally provided by diesel machine and diesel generator.

**Rolling System**

**Functions:**
- To hoist up and lay down the rod and drill head

When drilling a deep well, the rolling system has to lift weight of 300 tons. Figure 5 shows the profile of rolling system.
Rotating System

Functions:
- Cut the earth

Circulation System

Functions:
- Clear the drill hole
- Helps break rocks
- Cool drill head
- Take out the rock fragments
- The mud builds the wall of drill hole
Two Types of Drive for Drill

- Mechanical drive
- Electrical drive

**Typical power range:**

<table>
<thead>
<tr>
<th>Depth</th>
<th>Power Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2000 m</td>
<td>1200 kW</td>
</tr>
<tr>
<td>2000 - 3000 m</td>
<td>1500 kW</td>
</tr>
<tr>
<td>3000 - 5000 m</td>
<td>2400 kW</td>
</tr>
<tr>
<td>5000 - 7000 m</td>
<td>4000 kW</td>
</tr>
</tbody>
</table>

Figure 12: Mechanical Drill (Left) and Electrical Drill (Right)

**Typical Load Analysis**

**Phase 1: Hoisting**

- Hoist the entire rod: 1400 A
- Hoist and lay down a single rod: 500 - 1000 A
- 0 - 30 sec: 500 - 1000 A
- 30 - 60 sec: 1400 A
- 60 - 90 sec: 1400 A

Figure 13: Typical Load Circle of Hoisting

**Phase 2: Lay down**

Currently, the rod is mostly laid down by brake system:

- Main brake: Hydraulic brake
- Auxiliary brake: Water brake (for small or medium size drill) or Electro-magnetic brake

The function of auxiliary brake is to slow down the rod when it falls. It is desirable to remove the Auxiliary brake because of its cost and added complexity.
3. Special Requirements of Drilling Machine and its Solution

Specific Standards

Because the drill machine normally operates in remote areas, a specific standard is required. In China, JB/T 7845-1995 specifies the requirements for land drills.

Besides the general requirements, the following points are specified:
- **Explosion protection:**
  - The following equipment is designated as being in a zone 2 hazardous area:
    - Drill platform, Petrol controller, Pump controller and Electro-magnetic brake.
- Anti corrosion
- Transportation
- Supply by diesel generator
- Control house
- Load balance (Err Less than 10 %)

Small Power Supply

Normally, drilling machines operate in remote areas which have no power networks. Power is supplied from a separate diesel generator. This poses two limitations:
- first, power is limited; second, power cannot be regenerated.

Solutions:
- Constant power control (serial field DC motor, constant power control for AC and DC drives)
- Power limitation
- Current limitation
- Harmonic elimination
- Power factor compensation
- Choose special diesel generator (Power factor 0.7 - 0.8)

Size Limitation

Because drilling machines are frequently relocated, the drive system, MCC and diesel generator controller are mounted in a single control house, the size of each part should be as compact as possible.

Solutions:
- Reduce the SCR angle $\alpha$ (DC)
- Special motor (e.g. GE-752)
- Enlarge the content of single cubicle
- Simplify the system, e.g. no speed sensor
- Common bus

Reliability

Since the cost of drilling is quite high, it is very important to reduce downtime. If the well downtime exceeds 40 minutes the well may be shutdown as being uneconomic. For the advanced drill machine, the failure rate must be less than 0.01 %.

Reliability means:
1. long MTBF
2. easy to maintain
3. the machine continues to function at reduced capacity even if part of it fails
Solutions:
- Robust mechanic parts
- Reliable electrical parts
- Simplify the system
- Identical control parts (the rolling system and the mud pump)
- Redundant system
- Better protection against environment

Special Motor

The drilling machine motor has two characteristics:
- Small volume; Normally the motor has a long shaft.
- High degree of protection

GE company supplies motors specifically for drilling rigs, GE-752. In China, some manufacturers (e.g. Yongji motor factory) can produce similar motors. Siemens can also provide compact motor, which has been used in Daqing oil field.

4. System Configuration

Typical Arrangement of electrical Parts

![Diagram of system configuration 1 (DC)](image)

**Note:** Because a diesel generator cannot absorb energy, only single phase drive systems can be used for drilling machines. Although, in some cases, the drilling machine is supplied by power networks, then it is possible to use rectifier/regenerator system configuration.

![Diagram of system configuration 1 (DC)](image)
System Characteristic:
- Single phase system

Power supply:
- Power networks or Diesel Generator

Advantages:
- Can work anywhere
- Most economical
- Simple topology

Disadvantages:
- Cannot regenerate

Conclusion:
- A competitive solution

System Configuration 2 (DC)

Figure 16: System configuration 2 (DC)

System characteristic:
- Single phase system
- With a brake resistor

Power supply:
- Power networks or Diesel generator

Advantages:
- Can work anywhere
- Economical
- Brake resistor can absorb energy when rod decelerates

Disadvantage:
- The system reliability is reduced by the contactor.

Conclusion:
- This configuration is widely used by ROSS HILL company. The benefit of this solution is that the rolling system can decelerate faster.
System Configuration 3 (AC)

![Diagram of System Configuration 3 (AC)]

**Figure 17:** System configuration 3 (AC)

**System characteristic:**
- Single phase system
- SCR Rectifier

**Power supply:**
- Power networks or Diesel generator

**Advantages:**
- Can work anywhere
- Simple topology

**Disadvantages:**
- Can not regenerate
- Slightly more original investment than DC solution

**Conclusion:**
- Compared with the following AC solution, it is not promising.
System Configuration 4 (AC)

System characteristic:
- Single phase system
- SCR Rectifier
- With a brake resistor

Power supply:
- Power networks or Diesel generator

Advantages:
- Can work anywhere
- Brake resistor can absorb energy when rod decelerates

Disadvantage:
- Slightly more original investment than DC solution

Conclusion:
- A promising AC solution.

Recommended Communication Configuration 1 (PROFIBUS)

Some data needs to be transferred from control house to drill platform (about 50 m). It is better to use communication than use direct signal transfer.
Advantages:
- Reliable
- Easy to maintain
- Compliant with EMC
- Low signal attenuation
- Elimination of cabling
- Open protocol

Disadvantage:
- Expensive

Comment:
- This solution is implemented by ROSS HILL company, but it is expensive

**Note:** Shielded cable is also required, to comply with EMC regulations

### Recommended Communication Configuration 2 (Remote I/O)

![Communication Configuration 2 (Remote I/O)](image)

**Advantages:**
- Reliable
- Easy to maintain
- Compliant with EMC regulations
- Low signal attenuation
- Elimination of cabling
- Lower cost

**Disadvantage:**
- Special protocol

**Comment:**
- This solution is a more appropriate solution for drill machine, because it is not necessary to put a PLC in drill platform.

**Note:** Shielded cable is also required to comply with EMC regulations
5. The Special Features of our Solution

To fulfil the control requirements of drilling machines, our competitors, like ROSS HILL, need a PLC. Siemens are able to meet these solely with the control system built into our drive systems MASTERDRIVES or DC MASTER. This means that the interface is clearer, and the system inherently more reliable.

**Note:** All the functions have been realised by SEDL.

**Pedal Switch**

**Description:**
To increase productivity, when the rod is being raised, the operator may add an additional short term speed value. This is activated by a pedal switch, internally this is realised with an auxiliary set point.

**Solution:**

![Pedal Switch Diagram]

**Rotating Tray Inhibition**

**Description:**
Winch (rolling system) and rotating tray (rotating system) are normally driven by a single drive system and mechanically switched. To protect rod, when two motors are mechanically coupled, rotating tray can only be driven by a single motor.

**Solution:**

![Rotating Tray Inhibition Diagram]

**Zero Point Protection for Winch**

**Description:**
The set speed of the rolling system is given by a potentiometer in the drilling platform. Due to the technology requirements, the potentiometer can only make sense when it rotates from zero. That is, an abrupt set point cannot be given at beginning. When the potentiometer is at zero, a switch signal will be activated.

Meanwhile, when the winch motor is running, the motor cannot stop if the motor fan stops. However, when the fan is on, the motor can restart.

Mud pump also has similar simpler functions.
Solution:

**Fan On**

**Enable**

AND

**Potentiometer at Zero**

AND

**Enable**

SET (Q = D)

D

Q

STORE

NOT Q

RESET

**Enable**

**Power ON**

**OR**

Figure 23: Zero Point Protection for Winch

**Current Limitation**

**Description:**
When the rotating tray is running, operator may change the current limitation.

**Solution:**

**Changeable Current Limitation**

**Current Set**

Figure 24: Current Limitation

**Load Distribution**

**Description:**
According to the standard for drilling machine, when two motors are electrically coupled, load imbalance should be less than 10%.

**Solution:**
To meet with this requirement without sensor, 6SE70-Application Manual (Page 200) introduces a load distribution solution. This solution has been successfully implicated by SEDL, and the static load imbalance is less than 1%.
Power Limitation

Description:
Generally speaking, for example, a 4000 m drill needs three diesel generators. To save energy, not all of those diesel generators run simultaneously, the generators are manually operated. This means that the drives can demand more power than is currently available. In this case the diesel generator has to be reliably protected. However, an additional more stringent requirement is that the drives operate automatically without demanding more power than is available. Although the generator can protect itself, it cannot satisfy the latter requirement. So, the drives have to automatically limit their power requirements.

The ROSS HILL drive system has this function, which is achieved with the use of an analog circuit. SEDL provides a novel solution, which has advantages over the ROSS HILL solution.

The generator controller can produce an output in the range from -0.8 to 0.6 when the power output changes more. The factor 0 means that the generator has reached it’s power limitation point, though it can still run for a short time while the factor is 0.2 or 0.3.

Solution:

Figure 26: Power Limitation

Explanation:
When the generator overloads, i.e. Generator Factor > 0, a smaller speed set point is implemented. Then, the power absorbed by the converter is sharply cut back. Afterwards, the Generator Factor will recover (< 0).
In that way, generator and converter are dynamically balanced to retain Generator Factor to Zero without obvious speed fluctuation. As a result, the power is limited and converter can still run.

ROSS HILL reduced the power by cutting back the current, so the system response is much slower. That means the power factor sometimes exceeds 0.

6. **Our Competitive Edge**

- All drives are certified to DIN ISO 9001.
- We are able to provide a complete solution for industry, which includes drives, automation and low voltage controller.
- The complete digital closed loop controller is superior to conventional analog technology.
- **Automatic self-parameterization** makes commissioning easier.
- **Reproducible** parameters.
- **Large number of free logic blocks**: Control requirements can be satisfied without the need for a PLC. Parameterization can change I/O ports and open/closed loop logic without changing hardware.
- Large number of applications in China.
- Strong communication capability of our drives makes controller an integral part of automation system.
- Equipment fully tested prior to delivery.

7. **Several extra Topics for Discussion**

**DC Drives v.s. AC Drives**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DC</strong></td>
<td>SCR device</td>
<td>Simple structure</td>
</tr>
<tr>
<td></td>
<td>Mature technology</td>
<td>Low original investment</td>
</tr>
<tr>
<td><strong>AC</strong></td>
<td>IGBT device</td>
<td>More reliable</td>
</tr>
<tr>
<td></td>
<td>Developing technology</td>
<td>Simple motor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Possible to eliminate auxiliary brake</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Higher power factor</td>
</tr>
</tbody>
</table>

Since drilling machines operate in an extremely rigorous environment, AC motor is more competitive. According to the overseas report, for AC drives, it is possible to eliminate auxiliary brake. Thanks to that, AC drives will probably replace DC drives, because the auxiliary brake is expensive and fragile.

**Single Motor or Double Motors**

A typical rolling system is 1000 kW, so it is possible to drive it with single motor or double motors. Both are used in China.
Though the left solution is slightly more expensive, it is self-redundant. In that way, the system structure can be simplified.

**System Redundancy**

To increase the system reliability, ROSS HILL achieves system redundancy by using contactors.

If any rectifier or motor fails, the system can still run.

According to the depth of well being drilled, different motor combinations will be used. Due to these contactors, operator can easily change the combination by simply rotating a switch.

However, the system configuration is complicated. In order to make the system more reliable, it is better to adopt simpler configuration.

**Influence of the Energy stored in the DC Link Capacitor**

In the common bus system configuration, since large numbers of capacitors are paralleled. The energy stored in the DC link capacitor should be considered.

For a typical 4000 m drill machine, $C_{DClink} = 1.35 \, \text{F}$ (i.e. $270 \times 5000 \, \mu\text{F}$):

- $U = 600 \, \text{V}$, $U_{DClink} = 813 \, \text{V}$, $U_{DCmax} = 1000 \, \text{V}$.

The following energy stored in the DC link capacitor is obtained:
So, for every braking event of drill machine, 229 KW power can be saved. Since drilling machines start and stop frequently, this can amount to a considerable saving in energy.

8. Customer Benefits and Advice for Calculation

Comparing with a mechanical drill, an electrical drill is a great innovation.

Customer Benefits

- In the past years, many new technologies have been implemented to enhance productivity and shorten drilling times, such as horizontal drill, deep well and automatic drill. Horizontal drill, for example, can increase the well productivity up to six times. But such kinds of drilling technology require electrical drives.

- The efficiency of an electric drill can be up to 90 %. Especially, AC drive which can have a power factor of more than 0.9. Meanwhile, the drilling time can be greatly shortened by use of an electrical driven drill. That is, energy can be saved. Furthermore, field drilling is very time consuming, therefore saving time means saving money.

- Electrical parts have longer MTBF than mechanical parts.

- The motor and the mechanical parts of the drive system are protected by the electrical drive thanks to its controlled soft-start.

- Thanks to an electrical drive, the drill structure is greatly simplified. The installation time can be reduced to half. In addition, the transportation costs can also be reduced.

- For international projects, it is necessary to use the electrical drill drive system. This is very important for China, because China is very competitive in international project bidding thanks to the low labour costs. In fact, half of the electric drills in China are operating overseas.

- Fewer operators are needed for a drill team.

- The drives of SIEMENS have flexible communication ability, so they can seamlessly integrate with the automation system. This means, the drill can be better controlled and the Man Machine Interface is user friendly.

- Thanks to the free logic blocks of our drives, some technology functions can be fulfilled by the drives themselves. In this way, the area control unit is compact and the system is simple and the interfaces uncomplicated.

- The parameterization of several drives of the same size is easily done with the use of the OP1S or the PC-based SIMOVIS software.

Advice for Comparison Calculation

- The drill time for a certain well. For example, a 4000m well, how many days were taken by a mechanical drill in comparison with an electric drill?

- How much diesel oil was consumed by drilling a certain well?
9. Successful Projects

Application 1 (DC)

System configuration

![Diagram of system configuration](image)

**Figure 29: Application 1 (DC)**

**Basic data**

**Well depth:** 2000 m

**Motor:**
- Type: YZ02
- Voltage: 750 V
- Current: 1150 A
- Rated speed: 1060 r/min

**Rectifier:** 6RM2487-3KS10-1 and SITOR

**Generator:** 1000 kW, 600 V

**No speed sensor**

**End user:** Daqing Oil Field

**Partner:** Tianjin Ruilin Electric Ltd.

**Contract date:** Sept. 1998
Application 2 (AC)

System configuration

Figure 30: Application 2 (AC)

Basic data

Well depth: 4000 m

Introduction:
- Two 450 kW inverters for winch/rotate tray
- Two 400 kW inverters for mud-pump 1, 2
- Common DC-Bus
- E/F use SIMOLINK to approach same speed
- A/B, C/D load distribution

Diesel generator: 1000 kW (3 pcs)

No speed sensor

Interface diagram refer to appendix

End user: Xinjiang Oil Field
Partner: Xian Petroleum Exploration Complex
Contract date: Oct. 1999
10. References

*Electric and Automation Engineering Manual*
Chinese

*Mechanic Engineering Manual*
Chinese

*Outlook of World Oil Industry*
Chinese

[www.natoil.com](http://www.natoil.com)

11. Relevant Documents

Application for Land Drill
- Market Survey, market research, strategy Proposal
- Transparency for promotion

12. Contacts

Gao Chenghai
Siemens Electrical Drives Ltd.

174#, Jintang Rd
Hedong District,
Tianjin, 300180

P.R. China

Tel: 0086-022-24979797-248
Fax 0086-022-24977217
Email: ch.gao@sedl.siemens.com.cn
Siemens AG

Large Drives Division A&D LD

Competence Center Oil & Gas
Intranet: http://intra1.nbqm.siemens.de/oil-gas/index_00.htm